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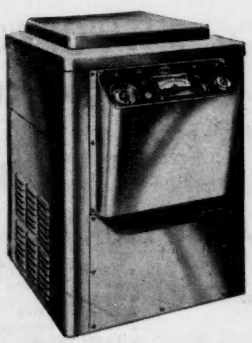

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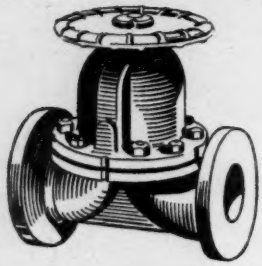

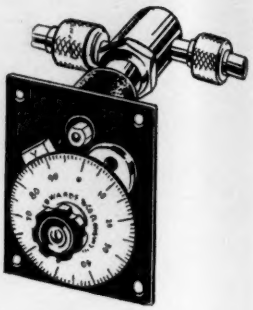

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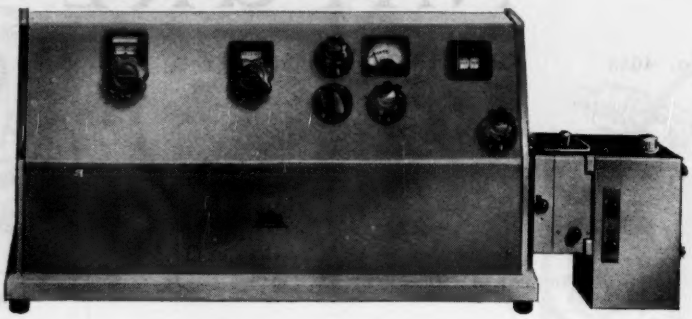

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The Faraday Society

The Council of the Faraday Society have accepted an invitation from the National Research Council, Ottawa, and Canadian Industries to hold a

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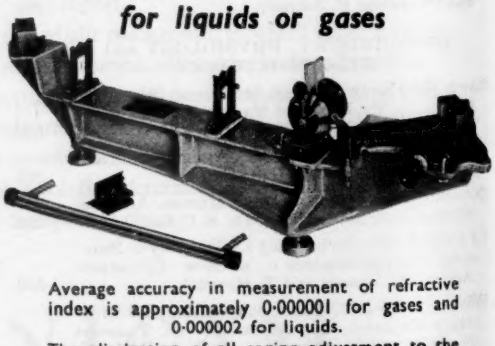

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CHURCHILL COLLEGE, CAMBRIDGE

ON January 24 the University of Cambridge passed without opposition a grace giving recognition to the proposed Churchill College as an approved foundation from the first day of the first term in which it admits students. Although outwardly no different from any other congregation in the Senate House, this was a historic occasion, for it marked the first approval of a new foundation for men in Cambridge since Selwyn College was admitted in 1882, and it means that the Trustees can now seek a Royal Charter and that Churchill may proceed in due course to achieve full status as a College of the University on equal terms with the older foundations. In its development to this stage of formal approval, the project has, naturally enough, met with some criticism in the University; but this has been less serious and less widespread than it has at times appeared to be from statements in the Press. The main lines of criticism have been on matters of procedure, on the clearly stated intention to have a numerical ratio of seven to three in favour of science and engineering in the student body, and on the vexed question of the desirable size of the University of Cambridge as a whole. Of the two latter, it has been pointed out, not unreasonably, by supporters of the project, that the growing importance of science and the current movement towards it in universities and more especially in our schools will, in any event, lead in the near future to a general bias in entries not unlike that proposed for Churchill and that since, under present conditions, pressure on entry to the University is so heavy, it is surely wiser to found a new college than to allow the system to be further weakened by a creeping inflation of existing foundations. It is significant that the grace approving Churchill College was accepted unopposed in the Senate House.

It is now little more than seven months since the Trustees launched their appeal, and the fact that more than £2,832,000 has already been subscribed, mainly by British industry, is a remarkable tribute both to the imaginative concept of a Churchill College and to Lord Knollys and his colleagues on the Appeal Committee. True, this sum still falls short of the original target by more than £650,000; but the Trustees hope that at least this sum may be obtained by their further efforts combined with those of the associated Churchill Foundation which, under the leadership of Mr. Carl Gilbert, chairman of the Gillette Co., is working to the same end in the United States. Already, however, the funds available ensure a firm foundation for the new College, and a number of steps have been taken to speed its development.

Building sites within easy reach of the main University precinct in Cambridge are nowadays difficult to find, but the Trustees have been fortunate in being able to purchase from St. John's College a large open site to the west of the river within 1½ miles of the city centre in an area close to that proposed for the new buildings for New Hall and Fitzwilliam House, to the Observatories and to the new University development area on the Madingley Road site. Bounded on the north and east by Storey's Way, on the south by Madingley Road and on the west by the grounds of the Observatories, the site extends to some 41 acres and will accommodate not only the College buildings but also its playing fields. Building a new College in Cambridge is an exciting project, and many different architectural approaches are possible. For this reason, if for no other, it was probably a wise decision to invite twenty firms of architects to enter a limited competition. The competition will be judged by a panel consisting of two Trustees and three distinguished architects, and it is hoped that the winning design will be translated into action within the year. The Trustees have given no indication of their own views on building; but it is hoped that the opportunity will be taken to build in the modern idiom, and to provide in the College buildings a permanent record of the best in mid-twentieth century architecture.

It has, of course, been clear that early appointment of the first Master of Churchill College would be necessary, since the beginning of a building programme will quickly bring in its train problems which require the Master's decision. Moreover, in preparing for the admission of students and in the initial stages of its work, a Master of outstanding quality is necessary if the College is to build itself into the Cambridge pattern and, at the same time, introduce new ideas and methods, and avoid the pitfalls which constructive criticism in the University has pointed out. The choice of Sir John Cockcroft as first Master will be widely acclaimed. Not only is he a brilliant physicist with a strong sympathy for engineering, but also his work in developing the Atomic Energy Research Establishment at Harwell has shown him to be an outstanding scientific administrator. More than this, he has long shown a strong interest in scientific education, and he is widely known as a man with a deep affection and respect for Cambridge and its traditions. With Sir John in charge, Churchill College should be off to a good start.

The announcement that future appointments to the Mastership will be made by the Crown has given rise to some discussion. Crown-appointed

masters exist in two colleges only—Trinity College, Cambridge, and Christchurch, Oxford—the common practice elsewhere being for masters to be elected by the Fellows themselves. Each system has its merits and demerits, but the evidence from Trinity and Christchurch suggests that appointment by the Crown can be very successful, and it provides at least some guard against the 'safe' but undistinguished elections made at times under the other system.

It is no easy task to build such a complex organism as a Cambridge College from scratch, particularly when it is sought to blend science and the arts in a predetermined ratio. Recruitment of staff and selection of students both present their own problems, and a gradual building-up process will be necessary; but these difficulties are offset by the opportunity to break new ground educationally. In their original memorandum the Trustees laid particular stress on postgraduate training in science and engineering for both home and overseas students, and they emphasized the need to encourage men to return from industry for a period of study and research. The provision of laboratory facilities and courses for such purposes will be the task of the University departments of science and engineering, but, through its tutorial facilities and specialist Visiting Fellowships which it hopes to maintain, Churchill College can make a new and important contribution to the Cambridge scientific scene. Much has been said and written about the need for a closer welding of science and the arts in our system of university education. Churchill College has the opportunity to experiment in this field, too, and we may hope that under Sir John Cockcroft's guidance it will not be overlooked. For teachers we must have, and, if Churchill College can produce men to lead in teaching as well as in industry, then it will indeed fulfil the high hopes of its Trustees and of its many benefactors and well-wishers.

NEURO-MATHEMATICS

The Computer and the Brain

By Dr. John von Neumann. (Mrs. Hepsa Ely Silliman Memorial Lectures.) Pp. xiv+82. (New Haven, Conn.: Yale University Press; London: Oxford University Press, 1958.) 24*s*. net.

THIS book constitutes the last writing to come from this eminent mathematician, a short account of whose life and last illness leading to his tragically early death in 1957 is given in a preface to the book by Klara von Neumann. The manuscript, intended for the Silliman Lectures in 1956, was never finished.

The first half of the book summarizes the characteristics of man-made computers. It distinguishes between analog and digital machines and the degrees of precision attainable in each, between parallel and serial methods of computation, between plugboard and memory-stored control, between active (arithmetic) units and inactive (memory) units, and discusses access times, memory capacities and so on.

The second half of the book compares the natural nervous system with artificial computers. It appears that the natural 'computer element'—the neurone—has a rather slow reaction time (10^{-2} sec.) compared with modern artificial devices. Von Neumann further implies that the method of transmitting information by digital pulse trains, interpreted in terms of pulse-time density to give digital-type logical information but analog-type quantitative information, will reduce the effective 'computing speed' by a factor of ten for each effective decimal place of accuracy. The loss of an occasional digit, however, would not be disastrous in the method of operation described.

On the other hand, he suggests that the effective memory capacity of the nervous system must be, and could plausibly be, of order 10^{20} decimal digits, in order to record a life-time of experienced sensations.

The overall picture is that the brain is, compared with modern machines, a very reliable and compact computer, with a low speed and a low order of accuracy in individual calculations, but an enormous (inactive) memory capacity, a large (active) arithmetico-logical assembly (highly parallel operation), and great economy in power requirements.

Von Neumann then argues as follows: since the brain has to control such a highly complex organization as the human body, it must carry out long (arithmetically deep) calculations. The brain cannot work to 10 or 12 decimal accuracy, which we know to be necessary in artificial computers, to retain two or three figure final accuracy. Hence, he argues that some different and unknown form of mathematics must be employed in the brain to produce its satisfactory results, and that conventional mathematics and brain-language stand in the same relation as an interpretive code to basic machine language, or vice versa.

In this connexion there are two relevant points, the first being hinted at by von Neumann himself, and the second, perhaps, being a point which he would have included in the book if he had been given time. First, the loss of accuracy at each stage of a long calculation may, perhaps, be eliminated by carrying out a large number of independent calculations at each stage, and evaluating the results statistically. By reason of its large 'active' assembly the brain would be well equipped to do this.

The second point is this: when planning a computation one has the choice between calculating everything *ab initio* (suitable for fast, small-memory machines) or using 'tabulated' results of earlier auxiliary calculations (suitable for slow, large-memory machines like the brain). The reviewer therefore suggests that the brain never does any arithmetically deep calculations—it merely makes minor interpolations, variations and extensions to a vast stock of 'tabulated solutions' which it has been accumulating (on a basis of trial and error and statistical selection) in its memory throughout the course of its development from a single cell. Really basic problems, like digestion of food and circulation of the blood, have perhaps been tabulated pre-natally for reference in this way. Slightly less basic problems, like learning to walk, have not been solved prior to birth, and it takes the infant's brain-computer many months to solve this problem. Even the adult's brain-computer may take a week to solve the rather simple problem of riding a bicycle. When obtained, this solution, or rather 'grid of experimental

results', is stored in the memory for future use by simple interpolation.

By bringing together two diverse bodies of knowledge—computer technology and neurology—the author wrote a most stimulating book, containing material for much further thought.

A. H. ARMSTRONG

SPECTRAL CASEWORK

Four Modern Ghosts

By Eric J. Dingwall and Trevor H. Hall. Pp. iii+8 plates. (London: Gerald Duckworth and Co., Ltd., 1958.) 15*s*. net.

THE first case concerns the repeated popping out of a book from a library shelf. In the authors' considered opinions the presence of a black nylon thread may have escaped the attention of the witnesses of the phenomenon. They then revive the late Harry Price's sensational story of how he visited an unnamed house and witnessed the most extraordinary séance ever vouchsafed a sceptical investigator. The living, breathing, talking figure of the little girl Rosalie materialized within a sealed room. The medium disappeared soon after, and the persons present have never been traced. The authors conclude, as have many others before them, that Harry Price, whose romancing propensities they exposed in a previous book, must have invented the whole episode. The third case is a typical poltergeist, with unexplained knockings and movements of objects at night, especially when two youths are about, and one member of the family said to have been caught by newspaper reporters in the act of throwing a book. The authors preserve "an attitude of suspended judgement". Finally they deal with bumpings, tremblings and noises in a house in Ousedale, and here they succeed in clearing the housemaid suspected of responsibility and placing the blame on subsidence due to subterranean water.

To quote the words the authors use of Harry Price, they may not have "advanced our knowledge of the supernatural in any way whatsoever", but they give a good display of professional zeal. The question looms large in their discussions whether their former collaborator, Mrs. Goldney, was once taken in by Harry Price. In reference to the Society for Psychical Research, they comment mildly in several places that, until recently, no discussion of the seismic theory of haunting noises has appeared in the Society's publications, but they quote an ancient letter to *The Times* describing the Society's methods of investigation as fit to "provide contempt in Bedlam itself". In an ingenious juxtaposition of sentences they say that "Mrs. Goldney became Organizing Secretary of the Society" but fail to mention that Dr. Dingwall himself was once its research officer.

The authors advance the theory that Harry Price, from lack of inventiveness, placed his imaginary séance with Rosalie in Brockley where years before he had attended some fake séances. They say they have discovered "correspondence which proved positively that Price has revealed that the séance was at Brockley", but though they quote extensively from all sorts of correspondence they give absolutely no details about this discovery. One suspects this lapse must have lost them several points of 'investigationmanship'.

D. J. WEST

RESEARCH ON FOOD

Advances in Food Research

Vol. 8. Edited by E. M. Mrak and G. F. Stewart. Pp. xii+437. (New York: Academic Press, Inc.; London: Academic Books, Ltd., 1958.) 12 dollars.

Processed Plant Protein Foodstuffs

Edited by Aaron M. Altschul. Pp. xv+955. (New York: Academic Press, Inc.; London: Academic Books, Ltd., 1958.) 26 dollars.

The Microbiology of Fish and Meat Curing Brines

Proceedings of the Second International Symposium on Food Microbiology held at Cambridge (United Kingdom) in April, 1957. Edited by Dr. B. P. Eddy. Pp. vi+336. (London: H.M. Stationery Office, 1958. Published for D.S.I.R.) 45*s*. net.

Bibliography of Food

A Select International Bibliography of Nutrition, Food and Beverage Technology and Distribution, 1936–56. By E. Alan Baker and D. J. Foskett. Pp. xii+331. (London: Butterworths Scientific Publications; New York: Academic Press, Inc., 1958.) 63*s*.; 11 dollars.

Flavor Research and Food Acceptance

A Survey of the Scope of Flavor and Associated Research compiled from papers presented in a Series of Symposia given in 1956–1957. Pp. vi+391. (New York: Reinhold Publishing Corporation; London: Chapman and Hall, Ltd., 1958.) 10 dollars.

THE ever-increasing number of published papers on all aspects of science makes it more and more difficult for scientific workers to keep abreast of what is being discovered. The streets of London are to-day filled with complex machines designed to enable a man to move rapidly and comfortably from place to place, yet the net speed of movement is slower now than it was in the days of the hansom cab. In just the same way, the congestion of publications makes it as difficult to-day to be well learned in one's subject as it was in the earlier centuries of science.

There are several ways of dealing with the situation. To read all the published material is impossible; to digest the great fortnightly editions of *Chemical Abstracts* takes more time and determination than many of us can command; even to master the close-woven pages of the annual reviews is sometimes a heavy task. The editors of "Advances in Food Research" have chosen the more scholarly approach. They have selected six authors, three from the United States, two from England and one from Holland, and asked each to write a critical review. The result is an excellent book. G. W. Scott Blair discusses rheology in food research with all the mathematical erudition which we would expect for an article in such a volume, but also with philosophical urbanity which is equally to be welcomed. P. A. Raelofsen reviews the out-of-the-way corner of the fermentation industries concerned with the processing of cacao beans. A. C. Hulme deals with the biochemistry of dying organisms, namely, apples and pears. F. A. Lee and M. Milner contribute excellent articles, the first on the blanching of vegetables and the second on new methods to detect and eliminate insect-infested grain. The total impact of the book is to emphasize the axiom that the line between pure and applied science is a blurred one when good scientists write.

"Processsed Plant Protein Foodstuffs" is also an excellent compilation. With great thoroughness and in 955 pages the international team of thirty-eight

authors has amassed a reference book of documented information on oil-seed meals of every sort as well as on by-products of milling, fermentation and much else. To leaven the lump, R. F. A. Dean has contributed from the Medical Research Council unit in Kampala, Uganda, an excellent and balanced review on the use of these vegetable proteins in human nutrition.

"The Microbiology of Fish and Meat Curing Brines" consists of thirty-eight papers, mostly quite short. They will be of interest to the people who attended the congress at which they were originally read. Scientists whose interests in biology are more general will be prepared to wait until the observations, facts, comments and doubts reported here are fitted into a more complete picture.

The "Bibliography of Food" is a most systematic affair, ranging widely from lists of grocers' journals to Sumner and Myrback's monograph on enzymes—unexpectedly entered under "nutrition : vitamins". The compilation of a bibliography, however, is a treacherous business even if it is a 'select' one. But though the authors do list Plimmer's historical tables of food composition and omit to mention the workaday ones of McCance and Widdowson, all in all they deserve our thanks for their efforts to codify the sources of twenty years of information on food.

"Flavor Research and Food Acceptance", fathered by no live editor but by an institution, Arthur D. Little Inc., is very good in parts, notably the excellent sections by L. M. Beidler and C. Pfaffmann on the physiology and psychology of taste, respectively. Other chapters are on a different level. For example, it appears that an agreeable aroma is important for the sale of petrol as well as soup. The book is a marriage of commerce and science, and the marriage is not an altogether happy one. MAGNUS PYKE

INFECTIOUS DISEASES

Die Infektionskrankheiten des Menschen und ihre Erreger

Herausgegeben von Prof. Dr. A. Grumbach und Prof. Dr. Kikuth. Band 1 : Pp. xl + 1–840. Band 2 : Pp. iv + 841–1702. (Stuttgart : Georg Thieme Verlag, 1958.) 198 D.M. (zwei banden).

THIS work is the product of the experience of Dr. Grumbach of the Institute of Hygiene, Zurich, and of Dr. Kikuth, the well-known pioneer in malaria and chemotherapy, assisted by a number of German, Swiss and other specialists. It is written from a novel point of view—to facilitate the understanding of the laboratory and scientific sides of infective disease by the clinician, and of the medical side by the biologist. It is not a laboratory manual in that details of technical procedures are largely omitted, and it is entirely bereft of illustrations, but throughout the book the clinical and therapeutic descriptions are intimately related to etiology ; another title might have been "Clinical Microbiology".

The first part is occupied by a description of the general principles of the subject as a whole (such as virulence, epidemiology and immunity) and of the specific groups (bacteria, rickettsia, viruses, fungi, protozoa and helminths), followed by useful chapters on chemotherapy (by Klein), disinfection (by Roemer) and disinfestation (by Weyer). The second part forms three-quarters of the two volumes and is devoted to the individual infections. Each is considered under the following headings : signs and symptoms, morbid anatomy, infective agent, pathogenesis, epidemiology, diagnosis, treatment, prophylaxis and control. This uniform classification makes it easy for reference, while an up-to-date bibliography, at the end of each section, indicates original sources, methods, etc. The greatest attention is paid to the bacterial and virus diseases (about a thousand pages) ; the parasitic infections are considered in much less detail, and organisms of minor importance are omitted (such as *Sarcocystis*, *Pneumocystis*, *Trypanosoma rangeli*, *Isospora belli*, *Iodamoeba butschlii*). The book is clearly written and well produced, and is specially recommended to workers in temperate zones ; it will undoubtedly form a standard text-book on the subject of microbiology. P. C. C. GARNHAM

CHEMICALS AND INSECTS

Methods of Testing Chemicals on Insects

Vol. 1. Edited by Harold H. Shepard. Pp. iv + 356. (Minneapolis, Minn. : Burgess Publishing Company, 1958.) 40*s*.

THIS is the first volume of a work of which another one, or possibly two, further parts are projected. The preface says, "This manual is intended to describe methods used in studying any phase of the action of chemicals on insects", and this first volume is devoted to the more fundamental aspects of the subject and to general techniques. More specialized subjects, such as testing chemicals for wood impregnation, soil treatment, as repellents and acaricides, are reserved for the second volume.

The sixteen authors, thirteen American and three British, are mostly well known. Together they contribute fourteen chapters which may be given the following condensed titles : (1) cuticle surface ; (2) cuticle penetration ; (3) respiration ; (4) electrophysiology ; (5) circulation ; (6) radioactive tracers ; (7) resistance ; (8) topical application and injection ; (9) feeding ; (10) dipping ; (11) spraying surfaces ; (12) dusting ; (13) fumigation ; (14) synergism. It will be noted that methods for testing space sprays, mosquito larvicides and systemic insecticides are not included.

The chapters vary greatly in length (from seven to one hundred and five pages) and in the detail with which the subjects are treated. It appears from the preface that the editor has had some difficulty in collecting the contributions. Perhaps this is why so little attempt seems to have been made to impose on the authors a greater uniformity of presentation. For example, in dealing with the actual methods the author may simply refer to the literature, give an outline description and refer to the literature for details, or give a full description down to the last particular. Furthermore, authors are clearly uncertain how much attention to give to the vital subject of standardizing and handling the test insects and to discussing the relationship between the insects and the insecticide under the test conditions. Some scarcely mention these subjects while others treat them at great length and refer to much literature which more properly belongs to other chapters.

The work invites comparison with "Techniques for Testing Insecticides" by J. R. Busvine already reviewed in *Nature* (182, 486 ; 1958). Criticisms may be made of Dr. Busvine's book, especially of some of the explanations and interpretations he gives of the

experimental methods he describes, but it is a better balanced work and more logically planned. On the other hand, perhaps none of the chapters is as clear, accurate and complete as the best in the present book —for example, Chapters 8 and 11. The type is bold and the book is pleasantly produced. The index is extremely brief.

There is no doubt that many people engaged in testing insecticides will find this book useful and convenient as a reference work. But there is equally no doubt that the general planning of the book and the contents of some of the chapters could have been considerably better. The ideal reference work on this subject has still to be written. W. A. L. DAVID

NOISE THEORY

Principles and Applications of Random Noise Theory

By Dr. Julius S. Bendat. Pp. xxi+431. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1958.) 88*s*. net.

NOW that electrical science has within its grasp a wide variety of instruments of ever-increasing sensitivity, it is imperative that the design of such instruments should be such that the information obtained from them should be as little as possible dependent on random external influences. This problem occurs again in the general field of communication where it is desired to identify some desired signal in the presence of some completely masking spurious signals. The available knowledge in these fields has been collated and amplified in this book by Dr. J. S. Bendat.

It is essentially a book for the advanced student in the field of noise investigations, although the introductory chapters do give a very clear review of the basic mathematical concepts on which all the theory is developed. Correlation functions are here defined and the special significance to the engineer of the exponential-cosine correlation function is very wisely stressed. Other important concepts included in this introductory section are power spectra and their relationship with correlation functions, and also sampling theorems.

The book develops with a fairly detailed study of probability theory; its applications to a number of random variable situations follow, well illustrated by a few simple engineering problems. As a final consideration, a situation outside that where the normal distribution holds is considered, namely, the case of the distribution of a noise envelope.

With this background, the ultimate object of the book becomes apparent in the next chapter. This is devoted to an investigation of the design of a network which will produce with any specified error some stated function of an input signal which has been degenerated with noise. This analysis is extremely general, being an extension of the pioneer work of Wiener to less restricted situations. The further problem of separating a desired signal from two received signals, both of which are degenerated by independent random signals, is also considered and illustrated by a deep problem on control.

The author now illustrates the wide applicability of the exponential-cosine autocorrelation function by a consideration of a number of varied practical systems in which it is applicable.

In a practical determination of the errors of a system to which such an input is applied, computer techniques are very desirable. The design of analogue computers for such simulation studies is considered. The errors in autocorrelation measurements are studied, first with particular reference to signals that are random in the video range and later for signals which have first been demodulated from radio frequencies either by a linear or a square law detector.

The topic is exceedingly thoroughly treated by the author, and, although essentially of a mathematical nature, he has not failed to keep the essential engineering nature of the problem before him. R. A. KING

AVAILABLE ENERGY IN THERMODYNAMICS

La Thermodynamique et le Théorème de l'Énergie Utilisable

Par R. Marchal. Pp. xxx+208+7 planches. (Paris: Dunod, 1956.) 1580 francs.

IT would appear that the author of this book felt a mission to bring to the notice of engineers the concepts and theorems of available energy, which are too frequently ignored in engineering text-books. The chapter in which this subject is treated well repays close study, although it would be possible to improve on some of the methods of presentation. Unfortunately, the preceding five chapters, on the first and second laws and the properties of perfect gases, cannot be recommended as a good introduction to the later chapter.

In the preface the author sets himself against a course which, in attempting to be a monument of deductive logic, loses contact with reality, but he goes to the other extreme in failing too often to define his terms clearly. Failure to define 'heat' results in surprising confusion of thought in several places. In the presentation of the first law, system analysis is perfunctory and no mention is made of control surface analysis as such; this may account for a confusion between thermodynamic cycles undergone by systems and mechanical cycles of operation of engines. These confusions place severe obstacles in the way of students hoping to understand the later and more worth-while chapter on available energy.

Many will not agree with the author, a professor in the École Nationale Supérieure de l'Aéronautique, that the ease of their mathematical treatment justifies the early introduction of perfect gases, which receive undue prominence in the text. Nevertheless, their use permits the presentation of two very interesting charts showing the available energy (availability) in non-flow and steady-flow as a function of the temperature and pressure ratios of system and environment. The author does well to point out in a footnote that the chemist's uses of the functions F and G result as special cases from the engineer's more general study of availability functions, although the book does not deal with the analysis of combustion problems or chemical reactions. The last chapter, on the representation of fluid properties, contains a useful but brief treatment of characteristic functions.

While a study of the chapter on available energy may prove rewarding, the book cannot be recommended as a standard text on thermodynamics.

R. W. HAYWOOD

Social Class and Mental Illness

A Community Study. By Prof. August B. Hollingshead and Prof. Fredrick C. Redlich. Pp. xii+442. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1958.) 60*s*. net.

THIS book is the record of work done jointly between Prof. A. B. Hollingshead, who occupies the chair of sociology at Yale University, and Prof. F. C. Redlich, who is professor of psychiatry at Yale University School of Medicine.

As might be expected, the research is meticulous and explores a section of psychiatry which has been singularly neglected. Commencing with a history of the New Haven community and revealing interesting details of the earliest members, they then deal with the history of psychiatry there. This brings the book up to the present time and an examination of the problems they have set out to investigate. These are the different classes of society and the nature of the mental and nervous illnesses which are to be found associated with them, how the members of the different classes become patients and how their relatives react to the necessity for psychiatric treatment.

Strangely enough they find that the members of the wealthiest classes tend to be dissatisfied with themselves when they are ill, the middle classes have anxiety symptoms, and the lower class neurotics develop aches and pains. The very lowest class develops behaviour disorders rather than neuroses. Psychotics appear in greater numbers in the lower classes and this seems to be caused not by a downward drift in society but by something else, probably stress and strain, in the environment.

This book is well worth the study of psychiatrists interested in social factors, and it is to be hoped that future work along the same sort of lines will be undertaken in Great Britain. CLIFFORD ALLEN

Tupu-Tupu-Tupu

By Peter Krott. Translated from the German by Edward Fitzgerald. Pp. 232+25 plates. (London: Hutchinson and Co. (Publishers), Ltd., 1958.) 21*s*. net.

THERE seems to be no limit to the extent man will go in his quest for new knowledge. During the past thirty years the unparalleled discoveries in natural science have been accompanied by investigations in natural history which are themselves tribute to man's curiosity, resource, persistence, patience and courage. Birds and the not-too-dangerous animals, for example, have been observed with such diligence and devotion that many new truths about animal behaviour have been revealed. To join the swelling ranks of this fine army of observers comes Peter Krott, an Austrian who made his home in northern Finland and Sweden and who became captivated by the study of that very dangerous animal, the wolverine, or glutton.

Despite incredible difficulties and much stupid and hostile opposition from so-called 'sportsmen', Krott secured the support of the Swedish Forestry Department to carry out systematic studies of an animal of which little was known other than that in northern mythology it was reputed to be the incarnation of the Devil. Krott showed that the mystery surrounding the wolverine was largely because it lived a much more secluded life than other beasts of prey, was avoided even by powerful animals like the bear and northern lynx because of its fighting abilities, was capable of considerable domestication if caught young, exhibited ferocious territorial behaviour and would not tolerate other wolverines of the same sex in the territory. The book is well written and the translation from the German owes much to Edward Fitzgerald; it contains some remarkable photographs.

Basic Physics

By Dr. A. R. Meetham. Pp. xi+144. (London and New York: Pergamon Press, 1957.) 21*s*. net.

DR. A. R. MEETHAM deserves praise for what is indeed a bold departure from the standard method of presentation of physics at the Advanced Level of the General Certificate of Education. He admits, in the preface to his book, that intending university students will need something more advanced, but for the average fifth- and sixth-form pupils many of whom have no intention of making their living by physics and for whom the Advanced Level is the end of their study of the subject, the large number of historical facts, methods, reasons and proofs which they have to memorize, Dr. Meetham maintains, only tend to obscure the basic physical principles. Hence "Basic Physics" is shorn of all these details, representing Advanced Level physics, with everything human, historical and experimental eliminated. Mathematics is not excluded, but is used mainly only to express symbolically the relationships between quantities, and mathematical proofs are deliberately avoided. A glance at the book is sufficient to see that Dr. Meetham knows what he is doing and why, and that his subject-matter is good, sound physics, clearly expressed and well arranged in a connected pattern. However, in many places it becomes so bare that it consists merely of a list of definitions and formulæ. It is an excellent book for sixth-form revision and perhaps also for university scholarship candidates. It stimulates thought by its provocative attitude of expression and approach, and its frank re-statement of the fundamental processes of physics, but it is not an Advanced Level text-book of physics. S. WEINTROUB

Communications and Electronics Buyers' Guide, Who's Who and Reference Book, 1958–9 Edition

Edited by C. C. Gee, with the assistance of D. W. Dwyer. Pp. 360+156. (London: Heywood and Co., Ltd., 1958.) 105*s*.

THIS is a well-produced and well-edited book, large in bulk and price, but full of information likely to be of value to all engaged in electronic work. It covers the whole of electronics, and by including allied industries it is enabled to cover acoustics, materials, etc. The bias is strongly towards what it calls "capital-equipment electronics", and the consumer sector of the industry is only briefly covered since there are other sources of data on this.

The Buyers' Guide Section has several alphabetical indexes, and the first of these—the classified index of products—is probably the most important. Under each product are given the names of the firms manufacturing it. The Who's Who Section may be of some value, but there are better works of this kind. The Reference Section is certainly valuable; the product surveys are probably the most useful part of the whole book. In them, all known products under a heading are tabulated, together with their salient performance characteristics. The book vividly portrays the amazing recent growth of a major industry.

D. G. TUCKER

ORIGIN OF THE RADIATION NEAR THE EARTH DISCOVERED BY MEANS OF SATELLITES

By Prof. T. GOLD
Harvard College Observatory, Cambridge, Mass.

INFORMATION has been obtained, both by Van Allen and his group in the United States[1] and by Russian workers with satellites[2], showing the presence of an intense flux of penetrating particles over most of or all regions of the Earth at heights in excess of 600 km. The most detailed information to date comes from Van Allen and his group, and was obtained with the aid of the *Explorer* 4. Neither the spectrum nor the identity of the particles has yet been established; but it is clear that one is here concerned with a very major phenomenon, either in the outer zones of the Earth's magnetic field or indeed in the whole of our region of the solar system. The observations indicate an increase in the flux with height, and the *Explorer* data that go up to a height of 2,200 km. still showed the high rate of increase there. The energy-range of the charged particles concerned seems to extend from perhaps several tens of keV. to several tens of MeV. Intensities of the order of a few hundred particles per steradian per cm.^{2} per sec. capable of penetrating the shielding of 2·5 gm. per cm.^{2} have been recorded. At the low-energy end of the range there appear to be fluxes of the order of 10^6 or 10^7 particles per cm.^{2} per sec. per steradian.

In addition to the satellite observations, there exist the auroral observations indicating high fluxes and a very steep energy spectrum in an actual aurora[3,4]. As many as 10^8 electrons per cm.^{2} per sec. per steradian with energies of the order of a few tens of keV. are thought to exist in actual auroral formations, and to be responsible for much of the light emitted there.

For any of the energies concerned, and for either protons or electrons, it would be true that the Larmor radii in the Earth's magnetic field are very small compared with the radius of the Earth; and it is this fact that allows one to discuss all this flux under one heading and without a more complete knowledge of identity or spectrum. For example, a 10-MeV. proton at a height of 3,000 km. above the equator would have a radius of gyration of approximately 3 km.

It is very tempting to think of the auroral flux and of that observed at lower latitudes and greater heights by the *Explorer* as being part of the same phenomenon. On that basis one can give a lower limit to the rate at which energy must be fed into the whole region from an estimate of the mean auroral brightness and the efficiency of light production. Cosmic-ray secondaries have been discussed as a possible source for this particle flux[5], and although neutrons scattered from the atmosphere and decaying there would provide a means of supplying such a flux, the total energy obtainable falls short by a factor of 10,000 for supplying the mean auroral light. The auroral flux can thus not be thought of as being a flux of stored particles in captured orbits in the Earth's field produced by cosmic rays and diverted through the magnetic disturbance into the auroral atmospheric zones. Some other and enormously more energetic source of supply for this flux must be found.

To clarify the requirement for the injection mechanism, let us consider first the range of orbits possessed by these particles. A charged particle in this energy-range liberated at some height above the atmosphere on the equator would in general spiral around the lines of force and thus proceed to a higher latitude and lower height (Fig 1). It would thus travel into a converging magnetic field and, as is well known, the pitch angle of the spiral orbit (that is, the angle between the trajectory and the magnetic field) would become larger and reach 90° at a particular point. In effect, the particles would be reflected and travel with the guiding centre closely following the line of force to the corresponding point in the other hemisphere. The position of the reflexion point, or the field-strength that occurs there, is defined by the field-strength and pitch angle of a particle at any other point of its trajectory through the good approximation that the magnetic moment of the orbiting particle must remain constant. The reflexion point is then given by the place where the field-strength reaches the value $B = B_0/\sin^2 \psi_0$, where B_0 is the field-strength at some other point on the trajectory and ψ_0 is the pitch-angle of this trajectory there.

The observed flux must thus be due to particles that oscillate quickly in spiralling orbits between the two hemispheres with a distribution in latitude related to the distribution of pitch angles.

This rapid oscillation, with periods of the order of a fraction of a second to seconds, is, however, not the only motion taking place. For the dipole-like field, the field-strength has a gradient not only along the lines of force but also across them. A slow drift motion of spiralling particles then occurs in a direction

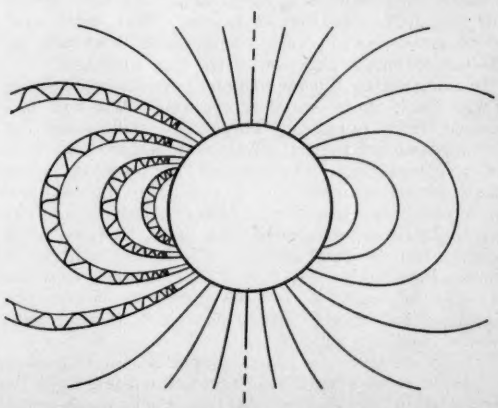

Fig. 1. Lines of the Earth's field and a schematic representation of some spiral orbits of charged particles showing the oscillation between the two hemispheres, and the reflexion in the converging fields

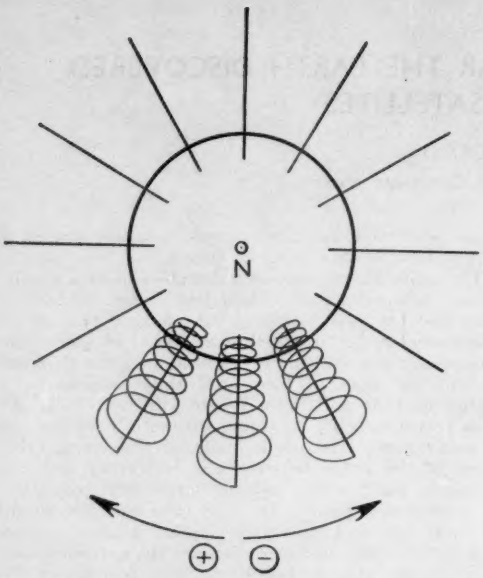

Fig. 2. Captive particle orbits, schematically, as seen from above the North Pole. Electrons will drift slowly eastwards, positive ions westwards

normal to the field and normal to its gradient, and for a perfect dipole field this would be a motion in longitude. This migration would take the particles once around the Earth in a time that depends upon the particle energy and the height of the orbit, but would generally be between a few minutes and a few hours. For a perfect dipole field and in the absence of any scattering by gas molecules, this would be the complete description of the types of motion that can occur.

The actual field of the Earth is very substantially different from a dipole field, as, for example, there are large regions on the surface where the field-strength differs by as much as 20 per cent from that which would result from the otherwise best-fitting dipole. The non-dipole parts of the field now provide a further type of drift motion of the particles, and, as there are gradients of the field in longitude, there will be drift motions in height. The individual orbits then become very complicated, and will in effect represent a diffusion of the flux in height.

In addition to the non-dipole, permanent features of the field, there are the magnetic variations impressed from outside. These also will make for complicated orbits that effectively diffuse the flux. As the non-dipole components of internal origin diminish faster with height than the dipole field, while the proportion of the field-strength due to the externally impressed variations must increase with height, the external effects will dominate above a certain level. Also the type of orbit changes that can be effected with a time-dependent field may be significantly different from the drift motion in a steady field.

There are then the four different modes of motion of particles, each with a different time-scale: (*a*) the gyration in the field; (*b*) the quick north–south oscillation along lines of force; (*c*) the drift in longitude; (*d*) the drift and diffusion in height. Of these motions, it is only the last the time-scale of which cannot easily be calculated; but it is certain that this motion is much slower than the drift in longitude. As molecular collisions are rare, leading to time-scales of many years[5] for the flux stored in a perfect dipole field, it is also most likely that the drift in height is the main agency for the removal of particles from a given zone. An upward drift would result in a loss of particles from the vicinity of the Earth, while a downward drift will result in their dissipation in the atmosphere.

For all but the highest particle energies, the magnetic moment of the orbiting charge must remain constant throughout the motion. The migration in the field will therefore be limited for any particle to the region in which the field-strength is less than $B_0/\sin^2\psi_0$, where B_0 and ψ_0 are the field-strength and pitch-angle, respectively, at some point along the orbit. Of a particle flux injected at a greater height only a certain proportion, namely, that injected with steep enough pitch-angles, will be able to reach the lower level. The equatorial regions are therefore accessible to a larger proportion of the particles than the higher latitudes where the field-strength at a given height is greater.

The migration of particles by molecular collisions is an insignificant process, as many more collisions would be required to cause a significant displacement than to dissipate the particle energy. But this does not mean that collisions are unimportant, for in a single collision the pitch angle of a particle may be changed from a flat to a steep one, and the region accessible to further migration will then be greatly increased.

For any flux with particle energies above some tens of MeV. the rule of the conservation of the magnetic moment would not apply accurately any longer, and the vertical migration would therefore not be subject to the same strict limitations.

With these properties of the flux in mind, let us now consider the consequences that would result from a supply of such particles initially isotropically at a point at, say, 5 Earth's radii above the equator. Of the isotropic flux, a small fraction would be travelling very nearly along the lines of force, and that fraction would be able to reach immediately to high latitudes and low heights. All the flux within a certain small angle to the lines of force would thus reach into the atmosphere and be dissipated there. The immediate effect would thus occur where the particular lines of force on to which the particles were supplied dip into the atmosphere, and an auroral luminescence lighting up these lines can be expected. The flux will thus suffer a change, in that the steepest-pitched particles are removed. Also a spread in longitude will set in through the action of the drift in the dipole field, and this spread will be fastest for the highest energy particles. Particles will thus be supplied around the entire belt of magnetic latitude, but will not dip quite so deep into the atmosphere. One would thus expect an auroral luminescence at a higher level, stretching out around the entire auroral bands.

For a perfect dipole field concentric with the Earth the drift motion in longitude would merely result in a steady weakening of the aurora along the belt in the direction of the drift (eastward for electrons), as the steeper pitched particles get removed. But in the actual case where the best-fitting dipole is significantly off centre, and where the non-dipole components are significant, this variation in longitude must be expected to be quite different. At some

particular longitudes on the Earth where the field at a given height is weakest the reflexion points of particles will be lowest, and therefore a flux will penetrate into the atmosphere there that had escaped dissipation at other longitudes. Such places in the field ought, therefore, to show auroræ always following an injection of particles and an aurora at any other longitude. The detailed dependence upon longitude can also reveal the sign of the charges of the particles responsible, by the sense of the longitude drift motion that would give the observed effects. Thus a local minimum in the field ought to have the greater auroral activity generally to the west if electrons are responsible.

If the original supplied flux was isotropic, then only a small fraction, of the order of 1/1000, will have been in steep-pitched auroral orbits. All the remainder will drift around the Earth and will gradually be distributed in height through the action of the inhomogeneities and the variations of the field. This distribution in height will happen comparatively quickly down to levels where the field-strength is such that no change of magnetic moment of a particle is required to reach there. Thus the steepest-pitched particles of the original flux that are left over will be the ones to migrate to the lowest levels, and they will be able to reach such field-strengths as they reached above the auroral zones without striking the atmosphere.

Without a detailed understanding of the complicated orbits leading to the diffusion in the field, the following general statements can still be made. First, the flux will get weaker as one goes away from the place where it was supplied. Secondly, time variations in the supply of particles to the system will be smoothed out with time constants given by the diffusion time that occurs between the point of supply and the point observed. Such diffusion times may well be a matter of weeks or months for the inner zones that have so far been observed. The flux that has suffered the longest migration in the field can be expected to show the least time variations and to show a tendency for the lines of constant intensity to follow not the field lines but the lines of constant field-strength. A shallow maximum of a rather steady flux above the equator is therefore to be expected, and it seems to be found in Van Allen's data. The lower regions of this zone have to be identified with the auroral belts, while above the equator the zone would be at a height of 4–6 Earth's radii. This zone has often been suggested as the supply route for auroral particles. In the present discussion I essentially add only the consideration of the fate of all those particles, several hundred or a thousand times as many for the case of isotropic injection, that travel in insufficiently steep-pitched orbits to reach down to the atmosphere and cause an aurora before being reflected in the converging field.

If observations of the particle flux are extended to greater heights above the equator one would therefore expect a continuation of the increase with height up to perhaps 5 radii, with a marked increase in variability and dependence upon the magnetic storm phenomena. The amplitude of the variations will, however, remain much smaller than those of the auroral flux, for even there the majority of particles will be in stored orbits that do not dip into the atmosphere. Beyond this height the flux will depend on the method of supply from the Sun, known to be highly variable.

If the phenomenon is thus interpreted, then the process of supply is intimately related to the magnetic-storm effects. It is thought that solar outbursts propel gas masses to velocities of the order of 1,000 km./sec., and that a magnetic storm phenomenon results when such gas masses strike the magnetic field of the Earth. On the scale of the phenomenon and with the degree of ionization involved, there is no doubt that the conductivity is high enough to ensure that the magnetic configuration is the one determined by the flow that has taken place. Thus, if a cloud of material expands from the solar surface, then any lines of force that it originally possessed linking it to the solar surface must be drawn out and carried along into all the spaces reached by the cloud. Unless the initial field in the gas was zero, such a cloud will thus remain magnetically connected to the solar surface. In order to discuss what particle fluxes may be present in the cloud of energies higher than those merely corresponding to its bulk motion, one has to consider what fluxes may be available generally on the solar surface; for any such particles will be able to move freely in their spiral orbits along all the lines of force drawn out by the cloud, and they will continue to populate all the regions reached by the cloud.

It is known that great solar flare outbursts can produce an intense flux of cosmic-ray particles at energies reaching to more than 10 BeV. Similar types of phenomena, but on a much smaller scale, seem to occur very frequently on the solar surface, and perhaps even continuously. Thus a supply of particles accelerated to energies much smaller than 10 BeV., but very much above thermal speeds, may well be constantly available on the solar surface and therefore may always populate all the lines of force that have been dragged elsewhere by outbursts of gas. Any magnetic-storm cloud approaching the Earth may thus have a high particle flux in it.

The speed of travel of the cloud itself determines the magnetic configurations, because it contains the necessary momentum. The high-speed particles possessing a total momentum insufficient to make the major changes of the fields can only come here together with the bulk of the gas clouds, and there is then no conflict in the observation that particles of MeV. energies appear here after time delays corresponding to velocities of only a few hundred or a thousand kilometres per second (proton energies of the order of 1 keV.).

For a static configuration of the Earth's field, the captive particle orbits are, of course, in a region that cannot be reached by such particles coming from outside. Particles may, nevertheless, be placed there in the course of a disturbance of the field configuration, and the magnetic-storm phenomena known to be associated with auroræ need, therefore, to be discussed.

The magnetic observations on the ground during a magnetic storm indicate that the phenomenon is very variable in time and also in position. Two stations at the same latitude but separated in longitude by as little as 1,000 km. show markedly different fluctuations. The sources of disturbance up above must thus be thought of as being very patchy, and indeed the same conclusion results from the appearance of the auroræ. Such a small-scale patchiness cannot possibly be attributed to the cloud that has come here from the Sun, but must be a phenomenon set up in the vicinity of the Earth by an instability of the flow of the solar stream around the Earth's

field. Thus, if at a distance of, say, 5 Earth's radii there was not in existence a smooth surface dividing the terrestrial from the solar field, but a surface containing many fine corrugations or tongues with the scale of these variations not greater than a few hundred km., then this pattern would account for both the scale and the magnitude of magnetic disturbances on the ground.

For the small-scale features of this pattern, it would no longer be true to say that the dissipation of electric currents responsible for the fields can be ignored, and indeed such dissipation times may well be of the order of half an hour, which is the speed of many of the fluctuation phenomena observed. In that case, fast particles spiralling around the lines of one field which is decaying can be transferred to the lines of force of the other field which is being established in that space. A penetrating tongue of solar field can thus shed its particles into the terrestrial field as dissipation occurs.

The transfer of fast particles from lines of force of the solar field to the terrestrial one may also occur in a manner not involving any dissipative changes of magnetic fields. Shock waves in magnetized conducting gases are thought to develop a shock front at least narrow enough to be comparable with the ion radius of gyration in the magnetic field at thermal speeds. Particles of much higher than thermal speeds will therefore traverse such waves. At the instant when it is a shock front that divides the solar from the terrestrial gas, the fast particles are moving in fields that change substantially in distances short compared with their radius of gyration, and they will therefore not remain effectively attached to lines of force but distribute themselves to both sides of the wave. It is therefore to be expected that fast particles will appear in the Earth's field in orbits into which they could not have been placed without the magnetohydrodynamic effects associated with magnetic storms.

Van Allen has reported recently[6] that an increase in the flux of fast particles, as counted in the *Explorer* satellites, has been observed following a magnetic storm. R. R. Brown has observed[7] an excess flux of what may be interpreted as secondary X-rays during magnetic disturbances at balloon altitudes and at latitudes well below the auroral zone. As this is most likely a secondary phenomenon of the Van Allen flux higher up, it also suggests the dependence upon magnetic disturbance.

Further experimentation should be able to clarify the situation considerably. It should be possible to show, for example, whether the time variations become indeed greater at greater heights and higher latitudes. Magnetometer observations should indicate whether at distances of the order of 5 Earth's radii the field structure is frequently patchy. If the present considerations are correct, radiation measurements at such heights should usually show a slow decrease with height above the injection region, while occasionally, during a magnetic storm, a substantial increase should occur there. Rockets flown to greater distances from the Earth should be able to signal the magnetic and radiation conditions when they are enveloped in a magnetic storm cloud.

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[2] Vernon, S. N., and Chudakov, A. Ye, communication presented to the Tenth General Assembly of the International Astronomical Union, Moscow (1958).

[3] Van Allen, J. A., *Proc. U.S. Nat. Acad. Sci.*, **43**, No. 1 (1957).

[4] Winckler, J. R., Peterson, L., Arnoldy, R., and Hoffman, R., *Phys. Rev.*, **110**, 1221 (1958).

[5] Kellogg, P. J., *Nuovo Cimento* (in the press).

[6] Van Allen, J. A., communication concerning the results of *Explorer 4* read at the Royal Society meeting on "Space Research", London (November 1958).

[7] Brown, R. R. (in the press).

GEOPHYSICAL EFFECTS ASSOCIATED WITH HIGH-ALTITUDE EXPLOSIONS

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THE purpose of this communication is to indicate some geophysical effects which one would expect to be associated with high-altitude explosions of nuclear weapons or high-altitude chemical explosions. In addition to outlining the effects which one would anticipate seeing concurrent with high-altitude explosions, we will attempt to discuss two experiments which seem to bear on these problems: one was the Johnston Island nuclear explosion which was observed in some detail, geophysically, from the Apia Magnetic Observatory, and the other experiment is the recently reported high-altitude grenade shot at Woomera, Australia, which also seemed to be accompanied by geophysical effects.

The discovery by Van Allen and his collaborators at Iowa of the intense radiation belt surrounding the Earth has made it clear that stable trapped orbits of particles in the magnetic field of the Earth do in fact occur. We propose to discuss here the effects which accompany the release of these trapped Van Allen particles, as well as effects expected to be associated with the injection of additional particles from a nuclear explosion. Since the geometry of the trapping field determines the sort of effects to be expected, we will first discuss very briefly this geometry as it relates to our problem. Following this, we will describe effects characteristic of a nuclear explosion at high altitude, and finally, those to be expected from a large chemical explosion, also carried out at high altitude.

It is now quite generally recognized that the tubes of magnetic force surrounding the Earth act as a natural mirror, in which charged particles undergo helical paths oscillating between the northern hemisphere and the conjugate point in the tube of force in the southern hemisphere. The trajectories of these particles are determined by the pitch angles with which the particles pass the equatorial plane, and a given particle is reflected at that point in the field at which the trajectory becomes perpendicular

to the magnetic line of force. With a perfectly symmetrical field, and in the absence of gas in which energy would be lost, the particles would oscillate between the northern and southern hemispheres indefinitely. The presence of gas in which loss of energy can occur at the lower altitudes causes the particles to have a finite life-time in this motion between hemispheres. Because, for reasonable energies, the radius of curvature is small compared to the radius of the Earth, the particles oscillate back and forth almost along a given magnetic line of force. For example, for a 1-MeV. electron, the radius of curvature would be approximately one-tenth of a mile near the surface of the Earth. Because the magnetic field is stronger at small radii than at large, in addition to the oscillating motion from northern to southern hemisphere, the orbits of the particles precess at right angles to a radius vector and constitute a ring current because of this precession. For example, for a tube of force at the equator near the Earth's surface, the precession of the orbit around the Earth would occur in approximately one hour. Although the exact number of particles present in the trapped radiation is not at present known, one can set an upper limit to the total energy of particles because of the known fact that the external portion of the Earth's magnetic field constitutes less than 1 per cent of the field measured at the surface. This upper limit of the energy of trapped particles in the Van Allen radiation is approximately 10^{27} MeV., or about 1,000 moles of trapped 1-MeV. particles. This limit does not depend on whether the particles are positive or negative, since negative particles precess to the east and positive to the west, and both constitute an effective ring current producing a magnetic field in the same direction at the surface of the Earth.

Finally, because of the inhomogeneities in the field, and because of the diamagnetism of the plasma gas, particles injected at a given point will tend to be distributed radially in a manner which is not easy to calculate. It is believed that this trapped radiation is of natural origin. The sources of replenishing it must be: (1) streams of solar gas; (2) neutron albedo from cosmic rays; (3) debris from high-altitude atomic explosions. All three of these sources must certainly contribute to the radiation, but it is not clear as yet which source is most important throughout the various ranges of energy involved.

The geometry of the tubes of force is such that the release of trapped radiation from the radiation belt would, qualitatively at least, give a very nice description of the auroral phenomena. Because of this, it seems to us to be quite crucial to test the hypothesis that Van Allen radiation, when released, can produce auroræ. This might be accomplished by high-altitude detonations designed to release the natural trapped radiation. Most calculations seem to indicate that the density of trapped radiation would be highest in those tubes of force which enter the Earth at approximately the latitude of the auroral zone. It is even possible that at certain times the density of trapped particles in these tubes of force is determined by the diamagnetism of the plasma gas, and that these tubes of force can only be filled to the point at which this demagnetization makes the tube unstable. This condition of instability will occur at a somewhat smaller density of particles than that at which the energy density of particles is equal to the energy density in the Earth's magnetic field. For an auroral tube of force reaching a radial distance of approximately 4 Earth's radii and entering the Earth at a latitude of 60°, this critical maximum energy density of particles would be approximately 10^{-6} ergs/cm.^{3}. If the particles consisted, say, of 1-MeV. electrons, the density would then be 1 particle cm.^{3}. It should be noted that this limit is in agreement with that derived from the condition that the particles cannot contribute more than about 1 per cent to the field at the surface of the Earth. That it should be possible to release this trapped radiation by explosive means now at hand can be seen from the following argument.

Since the energy density of particles cannot exceed the energy density in the Earth's field, an explosion in which an appreciable fraction of the stored energy in the Earth's magnetic field is dissipated in kinetic energy should allow the distortion of the field to the extent that particles may be released. The energy which is stored in the magnetic field of the Earth external to the surface is 10^{25} ergs. This corresponds to the explosive energy of a 200-megaton atomic weapon. Since only a very small fraction of the total energy stored in the field need be supplied in a conducting plasma, it is clear that a very much smaller explosion than 200 megatons would produce geomagnetic and geophysical effects. In an explosion, an appreciable fraction of the gas involved is ionized, and therefore constitutes a conducting plasma. If such a conducting plasma with kinetic energy is released in the region of the *E*- or *F*-layer, the plasma will be trapped in the lines of force of the magnetic field and distort this magnetic field into a large bubble. Part of the energy of the bubble should then be propagated as an Alfvén wave along the tube of force, going from one hemisphere to the other. The initial effect of the explosion with respect to the trapped radiation would be that those particles with pitch angles which became flat in the vicinity of the magnetic bubble would no longer be reflected and would be released from the trapped radiation field. Since the particles spend most of their time at the regions of reflexion, a relatively large number of particles would be released from the local region by such a plasma explosion. It should be pointed out that this explosion must be carried out at a high enough altitude to enable the kinetic energy of the explosion to be converted into distortion of the magnetic field through the interaction of the plasma and the magnetic lines of force, and that collisions with residual gas of the atmosphere do not dissipate this kinetic energy in heat. For these conditions, a high-altitude nuclear explosion would be ideal. We shall see shortly that such a high-altitude explosion, however, injects so many high-energy beta-decay electrons that the effects of releasing the trapped radiation would be obscured by the injection of radioactive particles from the atomic debris.

The velocity of the bomb-injected particles is on the average greater than the velocity of the Alfvén wave, and the injected particles will therefore reach the conjugate point before the Alfvén wave can release the natural trapped radiation.

In any high-altitude explosion, in which an appreciable amount of energy is coupled between the conducting plasma and the magnetic field, one would expect to see the following geomagnetic effects:

(1) The production of auroræ at the region of explosion and also at the conjugate point in the opposite hemisphere.

(2) Magnetic disturbances at the surface produced by the primary effects of the flowing charges in the ionosphere, and possibly by secondary effects caused by the release of additional particles as the magnetic

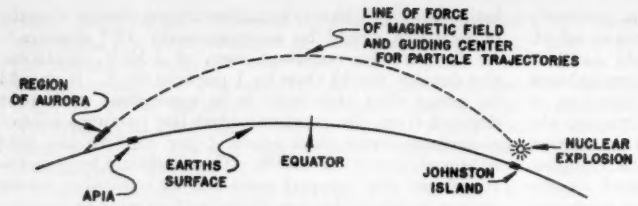

Fig. 1. Geometry of the Johnston Island nuclear explosion

field of the Earth becomes disturbed from the loss of the Van Allen radiation initially released.

(3) The propagation of an Alfvén wave, produced by the motion of the bubble along the lines of force. The Alfvén wave in this case may be thought of as a string wave in which the tension in the string is the tension in the lines of force, and the mass per unit length of the string is represented by the mass density of ionized particles which will be frozen to the line of force.

(4) Ionospheric radio effects. Because of the ionization produced by the released particles, which may have ranges up to several grams per square centimetre, there should be pronounced changes in the ionosphere, as evidenced by changes in the critical frequency of ionosonde soundings at both ends of the line of force.

(5) The presence in the upper atmosphere of the released radiation. This radiation could perhaps be studied from very high-altitude balloons, since the trapped radiation, once disturbed in pitch angle and allowed to penetrate down into the atmosphere, may have ranges in excess of several grams per square centimetre and could be detected at altitudes of 140,000–150,000 ft. by high-flying balloons. The bremsstrahlung from electrons stopped at very high altitude can be observed from balloons at 70,000–100,000 ft.

(6) The production of an artificial whistler by the propagation in the whistler mode of energy along the tube of force. This could perhaps be detected by the reception of audio electromagnetic waves at both ends of the tube of force.

(7) The effects can be used to locate magnetic conjugate points precisely.

Of the effects listed, we believe that the study of a 'point source' aurora is perhaps the most interesting, and an explosion properly carried out should be able to settle the question of whether auroræ can be produced by release of trapped radiation.

We shall now discuss the differences between nuclear explosions and those produced by chemical explosions in the *E*- or *F*-layer.

The Nuclear Explosion at Johnston Island

It has recently been reported in *Nature*[1] that at the time of the Johnston Island nuclear explosion geomagnetic disturbances were observed at the Magnetic Observatory at Apia; including visible auroræ, radio fadeouts, and a quite unusual magnetic storm lasting for several hours. We believe that the effects observed at Apia are in very good agreement with those expected from the injection of charged particles by the nuclear explosion at Johnston Island, rather than by the release of trapped radiation already present in that tube of force. The fact that the Apia observations were due to the Johnston Island explosion is indicated by the almost exact coincidence in time of the events and by the fact that such effects at low latitude as those observed at Apia on this occasion are extremely rare, only one previous case having been observed at this station. The time of the Johnston Island explosion was given as 12.52 a.m. Hawaii time[2], observed by an airline pilot flying over Hawaii who noted the nuclear explosion. This is 10.52 G.M.T., and the first observation of geomagnetic effects at Apia occurred at 10.51 G.M.T., August 1, 1958. The auroral display was observed in the west and south-west directions from Apia, and we have tried to calculate the impact zone of particles arriving in the vicinity of Apia along a line of force intersecting the northern hemisphere at 100 miles above Johnston Island. Fig. 1 shows a cross-section of the Earth showing the line of force along which the Johnston Island particles would be propagated. The thick line shows the region in which the particles would enter the atmosphere near Apia, and would produce auroræ. The altitude of the nuclear explosion is assumed to have been 100 miles—the altitude reported in newspaper accounts. The explosion must have occurred higher than 70 miles in order to be seen line-of-sight from Hawaii. The altitude at which the explosion occurs is that altitude at which flat pitch angles can occur (that is, orbit perpendicular to the line of force), and in fact flat pitch angles and reflexion cannot occur at a higher altitude than the altitude of the explosion. Steeper pitch angles, of course, can occur, and these will correspond to particles which penetrate deeper into the atmosphere at the other end of the line of force. At the atmospheric densities encountered at 100 miles altitude, the life-time of a 1-MeV. electron for loss of energy is approximately 20 sec. The easterly precession of the electrons, therefore, can only occur in a time corresponding to this life-time for loss of energy of the injected particles. The particles which will be propagated along the tube of force will be the beta-particles from the radioactive decay of fission or fusion products, depending on the nature of the bomb. These will be electrons and a few positrons in the 1-MeV. energy-range, and because the initial period of an atomic explosion is the most active one, the duration of the aurora will reflect the radioactivity of the products of the explosion. We believe that the five-minute duration of the aurora is a reflexion of this radioactivity rather than a life-time associated with the transmission or trapping of the particles.

Fig. 2 shows a plot of the expected impact area of the particles from the explosion, and the area in which the aurora was actually observed from Apia. The agreement is quite good, but the observed aurora seems to be north-west of the place expected from geomagnetic considerations. In order to calculate the geomagnetic conjugate point, we have used the position of the cosmic-ray equator, believing that it indicates best the direction of the tube of force. The disagreement between the calculated and observed impact areas may reflect uncertainty in our knowledge of the Earth's magnetic field, but might also indicate that the explosion, instead of occurring directly over Johnston Island, occurred somewhat to the south-west. Since the position of the impact zone agrees so well with the calculated position, one must inquire whether those particles arriving at Apia were released from the tube of force or injected by the atomic bomb. We have previously seen that

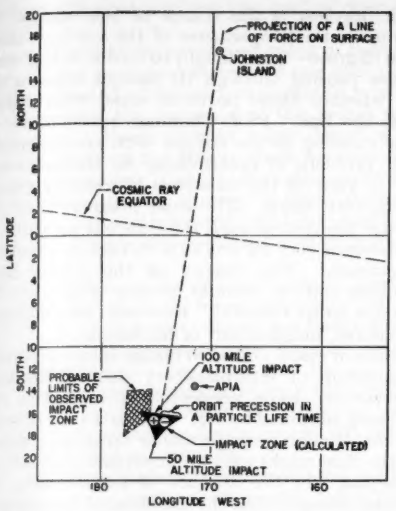

Fig. 2. Predicted and observed impact zones for the Johnston Island nuclear explosion. + and − refer to impact zones for positive and negative particles respectively

the total trapped radiation in the Earth's field represents perhaps 1,000 moles of particles. Because of the beta-decay following fission, approximately 5-10 moles of particles may be injected by an atomic weapon for each mole of fissionable material used. To get an idea of the order of magnitude of the injected *vs.* released particles, one might consider an explosion large enough to produce a kinetic energy equal to the Earth's magnetic field. This would presumably release all the trapped Van Allen particles, but it would in fact inject approximately 25,000 moles of beta-decay electrons, an order of magnitude more than the number of trapped particles already there. Since in the Johnston Island event we are considering a tube of force which reaches an altitude of only 400 miles at the equator, it cannot contain Van Allen radiation. The Iowa group finds the lower edge of the radiation belt at 1,000 km. It is quite clear in this case that many more particles will be injected than will be released, and that the auroral effects reflect these injected particles.

Chemical Explosions at High Altitudes

A recent *IGY Bulletin*[3] has reported observation of a luminescent cloud lasting three to four minutes following the explosion of a high-altitude sound-ranging grenade exploded at about 75 miles altitude. It seems possible to us that this luminescence could be produced by the release of naturally occurring Van Allen radiation. The rocket experiment was carried out at Woomera, Australia, at the end of a tube of force known to be populated with natural radiation. For an ideal experiment, with a chemical explosion at high altitude, one would attempt to carry out the explosion above 100 miles, and preferably at about 200 miles, in the *F*-layer of the ionosphere. It would also be desirable to have the ionization in the explosion as high as possible. Perhaps the addition of easily ionized material could increase the ionization in the chemical explosion. In the chemical explosion, however, the aurora observed, particularly at the opposite end of the tube of force, should be a definite proof of the possibility of its production by release of natural radiation. The detonation of a chemical weapon does not involve the problem of injection of charged particles from a nuclear bomb, but does suffer from the lower ionization in the chemical explosion. We feel that the detonation of approximately a ton of chemical explosive at 200 miles would produce a crucial test of this point.

[1] Cullington, A. L., *Nature*, **182**, 1365 (1958). See also Fowler, P. H., and Waddington, C. J., *ibid.*, **182**, 1728 (1958).
[2] *New York Times*, Aug. 2, 1 : 5 (1958).
[3] *IGY Bulletin*, No. 18 (December 1958).

SPACE RESEARCH

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THERE has probably never been a more rapid and far-reaching revolution in scientific technique than has been brought about by the advent of space-probing rockets. Between the end of the Second World War and the start of the International Geophysical Year more than one hundred upper atmosphere rockets were launched and a great deal was learnt, both about those regions and about the solar spectrum. In this period many techniques were developed which have been employed with even greater success in more than twice that number of rockets launched during the International Geophysical Year. With the use of geophysical rockets by the Russians, and especially of *Aerobee-Hi* by the Americans, the region between 100 and 300 km. above the Earth's surface has been explored with some thoroughness for the first time. At Churchill—in the auroral zone—and by launchings from a great variety of places, results have been obtained on the variations of many quantities with time of day, season and latitude. Most of the rockets fired had a useful life of only a few minutes, but this International Geophysical Year will be remembered also for the first launchings of artificial Earth satellites which made it possible to obtain world-wide coverage of the regions above 200 km. for weeks on end. During this time eight instrumented satellites have been launched and at least fifteen distinct objects have been placed into orbit around the Earth. In operation 'Farside', a multi-stage rocket launched from a balloon reached a height of 4,000 km. ; more recently the 'Pioneer' Moon shots penetrated to more than 100,000 km., while the recent Russian space probe passed close to the Moon and entered a solar orbit.

On a more modest scale, in Britain, the International Geophysical Year has seen the successful initiation of the Royal Society – Ministry of Supply research programme using *Skylark*, and the first

launching of *Black Knight*—a vehicle with great potentialities should it eventually become available for pure scientific research.

With the feasibility of direct experimental observation of the outer fringe of the Earth's atmosphere and of the nature and density of the corpuscular and electromagnetic radiation in the space beyond amply demonstrated, it was appropriate that a discussion of "Space Research" should be arranged by the Royal Society. In planning this two-day discussion, which was held on November 12 and 13, it was borne in mind that the possibility of direct study of the Moon and the nearer planets could not be long delayed, while the prospects for extensive astronomical observations carried out above the atmosphere were great. The kinds of scientific problems which could profitably be attacked by rocket techniques were examined, and the limitations imposed by the requirements of orbit and aspect control, vehicle tracking, data recovery and instrument design were discussed.

Although an invitation had been given, no delegate from the Soviet Academy of Sciences was present. However, the conference was fortunate to have present Dr. H. E. Newell of the Naval Research Laboratory, Washington, who was able not only to present many American results, but also to give a broad account of the future plans of the United States. The discussion was opened by Prof. H. S. W. Massey (University College, London), who reviewed briefly the scope of impending space research, mentioned the rapid technical advances that made these discussions important, and expressed his surprise to find himself speaking of developments in planetary studies that a year or so ago would have been simply science fiction. Experimental results and theoretical considerations relevant to an understanding of the atmosphere above 100 km. were discussed by Prof. D. R. Bates (Belfast). He limited his remarks to the composition and temperature of the region and assumed a static model. The composition is determined partly by diffusive separation, which has been demonstrated both by bottle-sampling and mass-spectrometric measurements. At 150 km. the argon–nitrogen ratio has fallen to one-sixth of its ground-level value. In a static atmosphere such diffusive separation would result in the concentration of hydrogen at 400 km. being comparable with that of atomic oxygen. However, a net loss or gain of hydrogen to or from the interplanetary regions would greatly affect the concentration gradient, and there is still a need for more experimental data.

Above 100 km. oxygen is largely dissociated and above 300 km. is probably more than ten times as abundant as atomic nitrogen. Below 300 km., due to rapid recombination of atomic nitrogen by $N + O_2 \rightarrow NO + O$ and $N + NO \rightarrow N_2 + O$, nitrogen is largely molecular and has a correspondingly small scale height. The ionic constitution up to 200 km. has been found to be principally NO^+ probably formed by $O^+ + N_2 \rightarrow NO^+ + N$.

The rise of temperature above 100 km. has been found to be much greater than was commonly supposed some years ago. The fall in the concentration of electrons above the *F*-layer—measured out to 750 km. by the Russians—suggested a temperature between 1,500° K. and 2,000° K. at this height. The large temperature gradient indicates a downward heat flux of about 2 ergs/cm.²/sec. and poses a considerable problem as to its origin. Prof. S. Chapman thought that the solar corona extends as far as the Earth's orbit, and, with a temperature of a quarter of a million degrees, is the source of this energy. The high maximum temperature of the corona—about a million degrees—was thought to be due to high-energy particles passing through it, though opinions differ as to whether these particles came from inside or outside the Sun. Prof. Chapman reviewed the conditions existing in the corona with special emphasis on the problem of determining its thermal conductivity in view of the existence of velocity gradients and magnetic fields. The solar magnetic field tends to rotate the corona with the Sun but probably does not penetrate very far out as it will set up an opposing ring current. The density of the corona beyond 15–20 solar radii is in doubt because of the centrifugal forces due to its rotation. However, its conductivity is, of course, independent of its density.

In spite of many efforts to obtain information on the concentration of interplanetary dust, difficulties of interpretation have prevented a consistent figure from being obtained so far. This is a pity because in sufficient, though perhaps rather unlikely, concentrations the dust might play an important part in cooling the corona. In the absence of such cooling, Prof. Chapman thought that the Earth must be regarded as a cool spot in an immensely hot gas and its atmosphere must rise in temperature from about 200° K. at 80 km. to 200,000° K. at great distances. The huge scale height implied suggests that the Earth's atmosphere may extend even as far as the Moon. The conductivity of the atmosphere due to hydrogen flowing into it might be increased five-fold because the atoms carry with them their heat of recombination.

Prof. C. F. Powell (Bristol) described the great potential value of artificial satellites to the study of fundamental problems in the physics of cosmic rays and very high-energy particles. He saw a limit to the particle energies attainable by contemporary methods at around 100 BeV. but in cosmic rays energies up to 10^9 BeV. are found. The satellite laboratory may well be the only place in which experiments on such energetic particles can be conducted for many years to come.

The abnormally high concentration of lithium, beryllium and boron in the cosmic-ray flux compared with their universal abundance is probably due to fragmentation of heavier particles during their interstellar journey. More satellite results are needed to confirm this. It seems probable, however, that a mean life of the order of 10^8 years is indicated. The long mean life and isotropic distribution suggest that the particles are stored in the fields of the galactic halo. Two possible sources of injection of these rays were contemplated, namely, supernovæ and in red and super-giant stars. Discrimination between these sources could be carried out by obtaining the mass spectrum of the rays well above the atmosphere. Thus a supernova source would result in rays rich in heavy elements, for example, thorium-254. Giants would give a spectrum similar to that of flare particles.

Satellites are particularly valuable in studying corpuscular and electromagnetic radiation from flares because of their unpredictable occurrence.

In a paper concerned with the study of the Moon and the nearer planets, Prof. T. Gold (Harvard) re-emphasized the need to study the density, motion, temperature and velocity distribution of material in the interplanetary regions. The magnetic field frozen into solar streams may entrap particles with energies ranging from 10 keV. up to 30 BeV. The importance of planetary and interplanetary magnetic fields places a high priority on a magneto-

meter in the allocation of the pay-load of deep-space probes.

A study of the Moon may be of value in helping us understand the geological history of our own planet. Facsimile scanning of the surface should be especially aimed to resolve the question of the origin of the lunar maria. A lunar satellite might detect a transient atmosphere on the Moon. Such an atmosphere could arise from gas emitted from the surface, or, when the Moon passed through a solar stream, as much as 3×10^5 particles/sec. might be found if the high-velocity stream were reflected with only thermal energy.

Satellite studies of the atmospheres of Mars and Venus could be carried out by spectrometric and mass spectrometric techniques. Even an Earth satellite could be of value in spectrometry of Mars, for example, since it would remove the confusion due to telluric lines. It would be interesting to look for suggestive traces of organic compounds of biological origin. The presence of water and nitrogen in the Martian atmosphere should be examined.

Prof. F. Hoyle (Cambridge) considered problems much more remote in space but in some cases quite as pressing in any plans for future space research. He reviewed the serious limitations to terrestrial astronomy occasioned by absorption, refraction, and scattering of light in the atmosphere. Astronomical observations made above the atmosphere with a 20-in. telescope would already have advantages over any made from a terrestrial observatory—quite apart from the unrestricted range in wave-length.

Use of narrow-band ultra-violet detectors, for the Lyman series, for example, would improve the signal/noise ratio for observation of distant objects because the red shift would separate the distant source from local scattering.

Studies of white dwarf stars in the ultra-violet would be especially valuable both because of their greater brightness in this region and because of the important nuclear reactions occurring in them. On the other hand, the use of infra-red detectors would make it possible to penetrate the dust clouds from which stars are formed, and would thus assist in an understanding of this basic cosmic process.

In the study of the Crab nebula and of the galaxy's gaseous envelope, where there are high-energy electrons, X-ray and γ-ray astronomy would be invaluable. Prof. Hoyle mentioned several examples of important cosmological data which we happen to possess simply because the atmospheric window is fortuitously well placed or because the limits of terrestrial vision are by chance favourable for observation. The argument that much more vital information awaits the extension of these limits seems inescapable.

Prof. A. C. B. Lovell was prevented by ill-health from attending, his place being taken by Dr. J. G. Davies of the Jodrell Bank Station, who pointed out that terrestrial radio astronomy is subject to the same basic limitations as optical astronomy. He thought that the greatest value of extra-terrestrial radio astronomy will lie in the extension of the useful spectrum beyond the ionospheric absorption limit, and in the possibility of close approaches to the Moon and planets.

Representatives of the Royal Aircraft Establishment discussed a number of practical problems in connexion with space probes and satellites. Dr. A. W. Lines stressed that stringent orbit and aspect control will be required in the near future. He set out to show how these requirements might be met in a satellite or space probe with an initial all-up weight of less than 100 tons and a first-stage thrust of about a quarter million pounds. Stabilization might be required in terrestrial, space (sidereal) or solar axes, and could conveniently be achieved by employing jet reaction initially, with motors for angular momentum storage after most of the angular momentum had been removed. Special emphasis was placed on a space stabilization system using two stars as reference points. The photoelectric equipment would be associated with gyroscopes to take control during eclipse of the stars. The precession-rate for the gyroscopes could be 'learnt' by the servo system by reference to the stellar vectors.

Mr. W. T. Blackband discussed a system for the recovery of information from vehicles as far away as the nearer planets. For a triode receiver, noise from all sources is a minimum at about 200 Mc./s., and corresponds to a source temperature around 750° K. Maser systems would give a better figure at very high frequencies. For a dish 10 m. in radius, a 10-W. transmitter and 1 c./s. band-width, Mr. Blackband obtained a signal/noise ratio of 1·2 at 10^8 km. It is evident that recovery of information is a major problem for planetary probes and recourse must be had to any or all of the following measures: considerable increase in transmitter power, even more drastic reduction of band-width, the use of masers, the use of directional aerials at the transmitter.

Position determination could be achieved by an interferometer calibrated against radio stars. A precision of 15 sec. of arc might be obtained. Stabilization of the transmitter to one part in 10^9 would enable range to be found by Doppler methods to an accuracy of 1 km. per hour of travel.

Techniques of physical measurements were reviewed by Dr. R. L. F. Boyd (University College, London). Two techniques, conspicuously absent in much work to date, are microwave spectrometry and the Langmuir probe. The former may ultimately prove a means of assaying directly the nitric oxide which plays such an important part in the ionosphere below 200 km. Some of the work at University College, London, was described. In 1959, *Skylarks* will be fired, equipped with Langmuir probes. Laboratory studies have shown that this technique may usefully be developed not only to give information on the concentration of electrons and temperature of the upper atmosphere but also to give concentration of negative ions and some degree of mass analysis. The extension of the technique to satellites and deep-space probes was discussed. Analyses of energy distributions at satellite velocities would enable discrimination to be made between oxygen and nitrogen atoms.

Considerations of Debye length, photo-emission and the return of collected current show that the technique might be applicable to a study of the solar corona and the energy distribution in solar corpuscular streams.

Prof. J. Sayers described the ionospheric work using *Skylark* rockets at the University of Birmingham. He showed a curve for electron density in a night sporadic-*E* cloud, obtained at Woomera on the Rocket World Day. It was remarkable for the thinness of the cloud—less than 3 km. Concentrations were similar to normal daytime *E* maxima. The method employed involved determination of the local refractive index from the frequency of a radio-frequency oscillator, the tank circuit of which included the insulated nose-cone of the rocket as part of its

reactance. Prof. Sayers also showed a *Skylark* nose-cone instrumented with an ion spectrometer of unique design. This spectrometer is a pulsed ion chamber of 2,000 cm.² aperture. It is ejected from the rocket on a long flexible cable so as to avoid contamination with rocket gases.

Probably the most dramatic and exciting discovery of the rocket and satellite programme of the International Geophysical Year has been Van Allen's work with the *Explorer* satellites, now corroborated by *Sputnik* 3. The discovery of the Van Allen belt, as it has come to be called, was made with *Explorer* 1, the Geiger counters of which were soon saturated with the intense radiation. To amplify the results from *Explorers* 1 and 3, *Explorer* 4 was instrumented with two scintillation counters (one plastic and one cæsium iodide) and two Geiger counters (one shielded). It was launched at an inclination of 51° and the results were recorded on magnetic tape, read out on command.

That the radiation belt reached a maximum intensity of more than 10,000 counts/min. at about an Earth's radius above the equator was confirmed by *Pioneer* 1. *Explorer* 1 showed evidence of a connexion between the intensity and auroral activity (and therefore solar streams). *Explorer* 4 indicated in addition the presence of a more penetrating component than the auroral electrons.

It was suggested that the radiation is largely due to solar ionized gas trapped in Störmer orbits. A rough computation of the relaxation time of the ionization gives 10^7 sec., far too long for auroræ to result directly from influx into the belt. It is suggested that the auroræ are due to leakage from the belt along the lines of magnetic force and that the increase at the advent of a solar stream is due to deflexion of the lines of force, analogous to a squeezing of the reservoir.

Mr. D. G. King-Hele of the Royal Aircraft Establishment, Farnborough, presented his results from observations of the orbits of *Sputniks* 2 and 3. The irregularities in motion can be attributed to varying air density, the westerly wind of the Earth's rotation and the second harmonic of the gravitational field. The results show that changes in air density at perigee are immediately reflected in change of time of meridian passage. The westerly wind causes a perceptible change in orbit inclination, while the rate of precession leads to an accurate estimate for the Earth's oblateness. If it is assumed that only the second harmonic of the gravitational field is significant, a new value of 1/298·16 is obtained for the elipticity compared with 1/297·6. Mr. King-Hele was of the opinion that to this degree of precision it is permissible to ignore higher harmonics. No inconsistency arises in the results obtained from satellites of various inclinations when this is done.

Two papers were presented by Dr. Newell. In the first he reviewed some of the results from inboard satellite instruments, other than cosmic-ray measurements. In the *Explorers*, micrometeors had been studied by the microphone method and environmental measurements had been made. Soon it was hoped to launch satellites to study cloud cover, the terrestrial radiation balance and magnetic field. Some micrometeor results have come from non-orbiting *Vanguards*. A flux of about $2{\cdot}5 \times 10^4$ kgm./day has been estimated but there are serious discrepancies with Soviet results.

The results on density obtained from rockets and satellites are consistent, figures of $2{\cdot}8 \times 10^{-13}$ gm. cm.$^{-3}$ at 228 km. being obtained from air drag and 1×10^{-13} and $8{\cdot}8 \times 10^{-15}$ gm. cm.$^{-3}$ at 260 km. and 355 km. respectively, from ion gauges in *Sputnik* 3.

Ionization shows a slow decline above the *F*-layer, and composition measurements using a radio-frequency ion spectrometer in *Sputnik* 3 show the oxygen ion to be the predominant ion from 250 to 950 km. The ratio of N^+/O^+ at 230 km. was found to be 3·7, rising by a factor of two at about 700 km.

In his second paper, Dr. Newell reviewed the future of American research under the National Aeronautics and Space Act. The terms of reference include: (1) expansion of human knowledge of the atmosphere and space, (2) aircraft, (3) space vehicles, (4) long-range uses of space for peace, (5) co-operation with other nations. The programme planned amounts to a review of all the basic physical studies which have become possible now that space research by rocket vehicles has become a reality.

NEWS and VIEWS

Geological Society: Awards for 1959

The Geological Society of London has made the following awards for 1959: *Wollaston Medal* to Prof. Pierre Pruvost, professor of geology at the Sorbonne, Paris, for his researches in stratigraphy and palæontology, with special reference to his work on the Carboniferous rocks of Europe, and his stratigraphical investigations of the rocks of Brittany; *Murchison Medal* to Prof. S. E. Hollingworth, professor of geology at University College, London, for his contributions to stratigraphy, glaciology and geomorphology in north-west England and the Midlands; *Lyell Medal* to Prof. D. Williams, dean of the Royal School of Mines, for his contributions to geology, especially as applied to the discovery and exploration of mineral deposits; *Bigsby Medal* to Prof. B. C. King, professor of geology, Bedford College, London, for his contributions to the structure and petrology of Africa, especially of Nigeria, Uganda and Bechuanaland, and to the interpretation of rock transformations, ancient volcanoes and metamorphic tectonics in Scotland; *Wollaston Fund* to Dr. M. H. P. Bott, lecturer in geology in the University of Durham, for his application of geophysical methods in the elucidation of geological structures and particularly the structure of granite masses; *Murchison Fund* to Dr. D. T. Donovan, lecturer in geology in the University of Bristol, for his work on Mesozoic stratigraphy, palæogeography and palæontology, particularly in regard to the ammonites; a moiety of the *Lyell Fund* to Mr. C. O. Harvey, chemist to the Geological Survey of Great Britain during 1934–58, for services in aiding geology by chemical analyses of rocks and minerals; another moiety of the *Lyell Fund* to Dr. W. H. C. Ramsbottom, of the Geological Survey of Great Britain, for his contributions to systematic and stratigraphical palæontology, especially for his work on the Lower Palæozoic Crinoidea and on Carboniferous faunas.

U.S. National Reliability Award : Mr. R. Brewer

Mr. Ralph Brewer, of the General Electric Company Research Laboratories, Wembley, has been awarded the 1958 National Reliability Award for his paper entitled "Life Tests of Electron Tubes and the Analysis of Failure Causes", which was read at the Fourth National Symposium on Reliability and Quality Control in Electronics, held at Washington in January 1958. The award is made to the author of the best technical paper presented at this annual Symposium. Mr. Brewer's paper was the only overseas contribution in the total of fifty papers read. The symposium is jointly sponsored by the American Institute of Electrical Engineers, the Institute of Radio Engineers, the American Society for Quality Control and the Electronic Industries Association. Mr. Brewer is a member of the principal scientific staff of the General Electric Company's Research Laboratories, which he joined in 1937 to work on illumination engineering. During the War he transferred to electronic valves and worked on early radar magnetrons. After the War, he took charge of valve reliability studies, which have played an important part in the development of improved valves. His work has now extended to cover the study of the survival characteristics of transistors and related semiconductor devices as well as the general reliability problems of electronic systems.

National Institute for Research in Dairying : Prof. R. G. Baskett

Prof. Ronald Gilbert Baskett has been appointed director of the National Institute for Research in Dairying, University of Reading, as from August 1, 1959. He succeeds Prof. H. D. Kay, who has recently retired (*Nature*, **181**, 1506 ; 1958). Dr. A. T. R. Mattick is at present acting director. Prof. Baskett is now professor of agricultural chemistry, the Queen's University of Belfast, and head of the Chemical and Animal Nutrition Division of the Ministry of Agriculture for Northern Ireland. He was born in 1901, and educated at King Edward VI Grammar School, Chelmsford, and University College, Reading, where he received his early training in chemistry with Prof. H. Bassett and Prof. H. A. D. Neville. His interests have centred in animal nutrition, particularly mineral metabolism. He has been especially concerned with pig husbandry and is at present a member of the Technical Committee of the Agricultural Research Council on Pig Research. Prof. Baskett has had long administrative experience in Northern Ireland coupled with teaching in the University of Belfast and examining in other universities. He also served with distinction as agricultural attaché at the British Embassy in Washington. His world-wide contacts with workers in the same field will be of great value in his new post.

Animal Husbandry at the Royal Veterinary College : Prof. J. A. Laing

The late Prof. N. J. Scorgie (see *Nature* of January 24, p. 220) has been succeeded in the Courtauld chair of animal husbandry at the Royal Veterinary College, London, by Dr. J. A. Laing, reader in veterinary science in the University of Bristol. Prof. Laing, who graduated in Edinburgh in 1941, took an early interest in problems of bovine infertility, and as an Aleen Cust Memorial Scholar worked under John Hammond at Cambridge, under whose guidance he obtained his Ph.D. in 1944. He remained in Cambridge studying particularly spermatozoa, as a research officer and then as veterinary investigation officer of the Ministry of Agriculture, until 1949, when he joined the staff of the newly formed Veterinary School of the University of Bristol. His main research interest did not waver from the general problems of animal breeding and genital infection and he attained a nation-wide and international reputation in this respect. In 1954 he was awarded a Churchill Fellowship to study in Copenhagen, and has acted as a consultant to the Food and Agriculture Organization of the United Nations, which sponsored an assignment for him to advise the Republic of Dominica on cattle infertility and allied problems during 1957–58. He was awarded the status of reader in 1957. His published works include the book "Fertility and Infertility in the Domestic Animals" (1955). Prof. Laing's breadth of experience in the field of animal reproduction will be of value in helping to develop the new field station of the Royal Veterinary College recently opened at Potters Bar.

Spert-III achieves Criticality

The special power excursion reactor test No. 3 (Spert-III), a versatile research facility developed for studying nuclear reactor safety at the U.S. Atomic Energy Commission's National Reactor Testing Station, Idaho Falls, achieved criticality on December 20. Spert-III is one of a series of reactors designed and developed by Phillips Petroleum Co. as part of the Atomic Energy Commission's programme to find basic explanations for the behaviour of reactors under runaway conditions. All operations are conducted by remote control, since some of the tests approach destruction of the reactor. This facility provides the widest practical range of control over three variables—temperature, pressure, and rate of flow of coolant. The plant is expected to contribute significantly to a better understanding of reactor self-limiting and occasional instability characteristics exhibited in an earlier experimental reactor, Spert-I.

Spert-I, which began operation in July 1955, was the first of a series established to investigate potential hazards associated with the broad class of heterogeneous, water-moderated, enriched-fuel reactors. Spert-II, which is still under construction, is intended to continue similar studies with special emphasis on how various moderators and reflectors, including heavy water, influence reactor behaviour. Tests in Spert-I, using a simple open-tank system, are generally characterized by sudden power rises (one reaching $2{\cdot}8 \times 10^9$ watts) that are arrested by the inherent self-limiting tendency of the reactor itself. Without any manipulation of the control rods, reactor power reaches a peak in a fraction of a second and drops off to much lower but generally steady levels. In some cases, however, instabilities also are observed following the power peaks. Some of these are divergent oscillations that could probably destroy the reactor, despite its self-limiting characteristics, if allowed to continue. The precise causes of self-limitation and of these power instabilities are not known, but form the principal objective of the present project.

Atomic Energy Information

In order to make atomic information more easily available, the U.K. Atomic Energy Authority has decided to make fuller use of microphotography. The effect of this will be to make all non-secret

reports which have been prepared since 1947 readily obtainable. Complete sets are also being presented to a number of other countries and to certain international agencies. In addition to this, the Authority is increasing its facilities for supplying reports in conventional form as they are prepared. From February 16 a large number of unclassified and declassified reports, which have hitherto been obtainable only on loan from Atomic Energy Authority libraries, will be available in micro form. Arrangements have been made with Micro Methods, Ltd., of East Ardsley, Wakefield, Yorks, for the production of microcopies on card of all unclassified and declassified reports issued between 1947 and December 1956 and, on a continuing basis, of those reports issued since 1956 which are not available on sale from H.M. Stationery Office. Microcopies may be purchased from Micro Methods.

Sands of Forvie Nature Reserve

Sands of Forvie, Aberdeenshire (1,774 acres), which has been declared a new Nature Reserve by the Nature Conservancy, under an agreement with the Walker Scottish Estates Co., Ltd., the owners, lies on the coast near Newburgh, between the mouth of the River Ythan and the village of Collieston. It consists of a broad foreshore backed by a line of dunes, behind which are slacks and more stable dunes passing inland to dune heath and rough pastures. To the north of the low sandy shore and the seaward dunes there are cliffs of schists and gneisses overlain by boulder clay. This rocky part of the coast includes Hackley Head and Hackley Bay. Inland from Collieston are two small freshwater lochs—Sand Loch and Cotehill Loch.

The chief botanical interest lies in the plant communities of the dunes. Marram grass (*Ammophila arenaria*) is the dominant species on the shifting dunes, while the sand sedge (*Carex arenaria*), the jointed rush (*Juncus articulatus*) and silver weed (*Potentilla anserina*) are generally among the earliest established dominants on the sheltered, moist dune plains. Mat grass (*Nardus stricta*), crowberry (*Empetrum nigrum*), creeping willow (*Salix repens*), cross-leaved heath (*Erica tetralix*) and ling (*Calluna vulgaris*) become prominent in later stages of the succession inland to the fixed dunes. The crowberry plants, conspicuous over large areas, are usually associated with lichens, forming a distinctive *Empetrum*–lichen heath community. The lesser spearwort (*Ranunculus flammula*) and the toad rush (*Juncus bufonius*) are characteristic of the wetter dune hollows which are often locally rich in mosses. Birds breeding within the area include eider (a particularly large nesting population), shoveller, shelduck, red grouse, little tern, arctic tern, common tern, sandwich tern, and fulmar. The whole area offers excellent opportunities for developing physiographical and biological observation and research. Among the dunes there are important Late Bronze and Early Iron Age sites which have yielded stone implements and pottery, and comprising stone circles, a flat ring cairn and kitchen middens.

Microbiological Defence Research

In reply to a question in the House of Commons on January 26 regarding the Microbiological Research Centre and the Chemical Defence Experimental Establishment, the Minister of Supply, Mr. A. Jones, said that the Ministry of Supply Establishments at Porton are mainly engaged in research on defensive problems of microbiological and chemical warfare. The investigations are essentially directed towards assessing the threat and providing defences against it, and most of the results obtained are published in the scientific literature. The danger from botulinus toxin is included, but this danger has been grossly exaggerated, since the toxin cannot be easily disseminated and is not self-propagating. Useful defensive measures against it are known.

Scientific Research in South African Universities

The Register of Current Scientific Research at South African Universities, 1957 (pp. viii+198. Pretoria: South African Council for Scientific and Industrial Research, 1958), is the fifth of the series of annual volumes listing research projects in the natural sciences being undertaken at South African universities and intended to meet the needs of research workers in South Africa and elsewhere. The information is given in the language in which it was received from the universities, but an English translation of Afrikaans entries is provided, and the alphabetical order of the subject-matter is determined by the English heading. As in previous volumes, entries are grouped under subjects, corresponding roughly with departmental divisions in the universities, and under these headings are arranged all the research projects in that subject in each university in turn. There are also an author and a subject index.

The Nucleus

In view of the spectacular advance made in recent years in the field of genetics, there is a growing need for more information about the physical basis of genetic phenomena. *The Nucleus*, an international journal of cytology and allied topics, recently published, has this aim (*The Nucleus*, **1**, No. 1; June 1958. Pp. 152. Calcutta: Dr. A. K. Sharma, Editor, Botany Department, The University, 1958; annual subscription 10.50 dollars or Rs. 46.00). The contributions in the first issue deal with descriptive cytology, chromosome dynamics, chemical and radiation effects on chromosomes and the mitotic process, and include a scholarly study on the possible role of nuclear membrane detachment in cytoplasmic organization. The international advisory board consists of H. Kihara (Japan), H. P. Riley, B. P. Kaufmann and J. H. Taylor (United States), F. Oehlkers (Germany), A. Löve (Canada) and M. J. Sirk (Holland). The editor is Dr. A. K. Sharma. The style of printing and the photographic reproductions can compare favourably with any other well-established publication.

Fourth Congress on Theoretical and Applied Mechanics

The fourth Congress on Theoretical and Applied Mechanics was held at the Bengal Engineering College, Howrah, during December 28–31, under the presidency of Dr. S. R. Sen Gupta, director of the Indian Institute of Technology, Kharagpur. About two hundred and fifty scientists and engineers, including members from Australia, Burma, Czechoslovakia, Egypt, Hungary, Italy, Japan, Poland, the United States and the U.S.S.R. attended. Some forty original papers were read, on subjects including finite deformation, visco-elasticity, stress waves, stresses in strips, columns and disks, plasticity, elasto-porosity, vibration and stability, fluid-flow, ballistics and statistics.

Dr. A. N. Khosla was elected president for the next two years; Dr. S. K. Chakravarty was elected vice-president in the vacancy created by the retirement of Sri V. Cadambe; Prof. B. R. Seth was re-elected secretary-treasurer for the next three years; and Dr. Jai Kishan, Prof. B. Sen Gupta and Prof. D. Banerjee were elected new members of the Executive Committee. The Executive Committee accepted the invitation of the University of Roorkee to hold the fifth Congress in Roorkee in December 1959.

The Emissivity of the Earth's Surface

Loss of heat by radiation from the Earth's surface is one of the fundamental physical factors of meteorology. J. T. Houghton (*Quart. J. Roy. Meteor. Soc.*, **84**, 448; 1958) describes measurements with airborne radiometers at night which permit a comparison to be made between the temperature of the Earth's surface and the black-body temperature of the radiating surface computed from the upward flux of radiation at 200 ft. and the temperature and humidity of the intervening atmosphere. At this height about 60 per cent of the upward radiation comes directly from the surface. The observations gave a black-body temperature between the screen temperature and the ground temperature. Thus on one occasion over north-east Hampshire the effective black-body temperature was 3·2° C., whereas the screen temperature was 4·7° C. and the ground temperature 2·7° C. It appears that heath and arable lands radiate as black-bodies with an emissivity of 100 per cent. One observation over the English Channel, however, gave an effective temperature about 2 deg. C. higher than the screen and sea temperatures observed nearby at the *Royal Sovereign* lightship. An observation made just above a layer of stratus cloud at 3,000 ft. gave an emissivity of 100 per cent for the cloud.

A Mongolian Earthquake

A VIOLENT earthquake occurred on December 4, 1957, in the region of the Gurvan Bogdo mountain chain belonging to the Gobi–Altai system. In January 1958 a joint Mongolian–Russian scientific expedition proceeded to this region, and a brief account of the findings is presented by N. A. Florensov (*Priroda*, **7**, 73; 1958). The region affected by the earthquake is a belt some 270 km. in length containing a system of branching fault fractures, many of them marked by very long fault scarps. The earthquake greatly affected overground and underground waters and the relief of the country.

Powder Patterns of Ferroelectric Domains

FOR more than fifty years red lead and sulphur have been used for picking out differently charged portions of the surfaces of insulators. Recently, however, G. L. Pearson and W. L. Feldmann, of the Bell Telephone Laboratories, New York, have used these substances in suspension in hexane to pick out positively and negatively charged domains, respectively, on the surfaces of ferroelectrics. The suspensions are applied separately; one after the other has dried on the surface under investigation. The lead oxide may be replaced by a dispersion of a cross-linked polymer derived from polystyrene. It is also found that colloidal particles of barium titanate, which have a very high dielectric constant, are deposited at ferroelectric domain boundaries, and this technique has given new information concerning domain structures of a number of ferroelectrics.

Four Rare Indian Animals

UNTIL 1952 there was no agency in India directly concerned with the preservation of the country's wild life, and the Forest Departments of the various States were able to give only a limited measure of protection within certain of the reserved forests under their jurisdiction. In that year the setting up of the Indian Board for Wild Life to advise the Central Government in New Delhi was an important event in Nature conservation in India. It was followed within a short time by the constitution of State Wild Life Boards in nearly all the States of the Indian Union. Now several States also possess separate Wild Life Departments, within the Forest Department, concerned solely with the preservation of wild life. The creation of these Boards at Central and State levels has not been followed by any remarkable results, nor has there been any marked improvement in the general position of wild life over the whole country. But the publicity given in the Press and elsewhere has succeeded in focusing public attention on the need to protect the country's rare and vanishing species and on the desirability of maintaining and developing wild-life reserves. As a result, writes E. P. Gee (*Oryx*, **4**, No. 2; 1958), the status to-day of the Indian rhinoceros, Indian lion, brow-antlered deer and Kashmir stag is more secure than it has been since the lowest recorded levels of these species.

Gordon Childe Memorial Fund

THE issue of *Man* of October, 1958, contains an appeal for a Gordon Childe Memorial Fund. Details have not yet been worked out and everything will depend, of course, on the amount of money available. Any friend or admirer of the late Prof. Gordon Childe can send a subscription, now, to the Secretary, University of London Institute of Archæology, 31–34 Gordon Square, London, W.C.1.

Ramsay Memorial Fellowships for Advanced Students of Chemistry

THE Trustees will consider in June applications for two Ramsay Memorial Fellowships for advanced students of chemistry. One of the Fellowships will be limited to candidates educated in Glasgow, who can apply to be considered for either Fellowship. The value of each Fellowship will be £600 per annum, to which may be added a grant for expenses of research not exceeding £100 per annum. The Fellowships will normally be tenable for two years. Full particulars can be obtained from the Joint Honorary Secretaries, Ramsay Memorial Fellowships Trust, University College, Gower Street, London, W.C.1. Completed application forms must be received not later than April 13.

Mond Nickel Fellowships

MOND NICKEL FELLOWSHIPS are intended to enable selected British graduates to obtain additional training and wider experience in industrial establishments, in Britain or abroad, so that, if they are afterwards employed in executive or administrative positions in the British metallurgical industries, they will be better qualified to appreciate the technological significance of research and to apply its results. It is also hoped that the training facilities provided will attract persons qualified in sciences other than metallurgy into the metallurgical field. Each Fellowship will occupy one full working year;

it is hoped to award five Fellowships each year of an approximate value of £900–£1,200 each. Further particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed forms must be returned not later than June 1, 1959.

The Creole Foundation Prize

The Creole Foundation, created by the Creole Petroleum Corporation—which is affiliated to the Standard Oil Company of New Jersey, and operates in Venezuela—with the object of encouraging the development of university, technical and industrial education and of scientific research in general, is offering a prize to be known as the Creole Foundation Prize. This will consist of 10,000 U.S. dollars and a diploma to be awarded to the author or authors of a work, selected through a competition, on any aspect of Venezuela in the fields of the natural, physical or social sciences. The prize will be given every two years in Caracas, beginning on October 17, 1960, the anniversary date of the creation of the Foundation; travelling and living expenses to Caracas will also be paid. Works to be submitted for the competition, which may be of any length and must either be written in Spanish, English, French, German, Italian or Portuguese or be accompanied by an adequate summary in one of those languages, must be received before December 31 in the year immediately preceding that in which the prize is to be awarded, at Premio Fundacion Creole, Apartado 889, Caracas, Venezuela, from which further information can be obtained.

University News: London

The title of professor of physiology in the University of London has been conferred on Dr. J. A. B. Gray in respect of his post at University College. The title of reader in physics in the University has been conferred on Dr. R. L. F. Boyd in respect of his post at University College; and that of reader in political economy in the University has been conferred on Mr. W. J. Corlett in respect of his post at University College. Dr. M. J. Seaton, lecturer at University College, has been appointed to the University readership in physics tenable at that College.

Announcements

Sir George R. Edwards, managing director of Vickers-Armstrongs (Aircraft), Ltd., and immediate past president of the Royal Aeronautical Society, has been made an Honorary Fellow of the American Institute of the Aeronautical Sciences. Dr. A. M. Ballantyne, secretary of the Royal Aeronautical Society, has been elected a Fellow of the Institute of the Aeronautical Sciences.

The Swiney Prize of the Royal Society of Arts for the best published work on medical jurisprudence has been awarded to Dr. Keith Simpson, reader in forensic medicine to the University of London at Guy's Hospital Medical School, for his book, "Forensic Medicine" (third edition). The Prize, which consists of £100 and a silver cup of the same value, is awarded on every fifth anniversary of Dr. George Swiney's death in 1844 for the best published work alternately on medical and general jurisprudence. The award is made by a joint committee of the Royal Society of Arts and the Royal College of Physicians.

On his resignation from the post of assistant secretary of the Royal Meteorological Society, Mr. M. E. Shoenberg has been made a life-member of the Society. His successor at the Society is Mr. R. H. Levinson.

Prof. A. N. Duckham has been appointed chairman of the Milk and Milk Products Technical Advisory Committee of the Ministry of Agriculture, Fisheries and Food in succession to Prof. H. D. Kay.

Griffin and George (Research and Development), Ltd., has been formed by the Griffin and George Group to conduct research into, and the development of, new and improved scientific instruments and apparatus for laboratory use and process control. Dr. A. J. P. Martin, well known for his work on partition chromatography, acknowledged by the award in 1952 of the Nobel Prize for chemistry (jointly with Dr. R. Synge), has been appointed research director.

The Ergonomics Research Society is holding a symposium on "Ergonomics: its Place in Industry" in Oxford during April 6–9. The symposium is intended to provide an opportunity for reviewing progress in the field of ergonomics research and application and for considering future developments in this field. Further information can be obtained from Dr. S. Griew, Department of Psychology, 22 Berkeley Square, Bristol 2.

The Institute of Physics is arranging a one-day symposium entitled "Current Developments in the Production of High Vacua", to be held in London on April 17. There will be three sessions devoted to chemical and ionic pumping in kinetic vacuum systems; problems in the production of high vacua in large equipment; and analysis of residual gases in kinetic vacuum systems. Abstracts (but not preprints) will be circulated before the symposium, the proceedings of which will not be published in full. All inquiries should be addressed to the Secretary, Institute of Physics, 47 Belgrave Square, London, S.W.1.

The University of Liverpool is arranging a special Conference on Mathematics, to be held at Derby Hall, Liverpool, during April 5–11. The Conference is intended to provide an opportunity for teachers of mathematics in grammar schools, technical colleges and universities to meet mathematicians employed in industry, government establishments and research organizations, and learn something at first hand of mathematics in action. Prof. Louis Rosenhead will be chairman of the Conference, which will be mainly residential, but arrangements are being made to enable local teachers to attend on a non-residential basis. Inquiries should be addressed to the Director of Extra-Mural Studies, The University, Liverpool.

The Proceedings of the International Congress on Radiation Research, held in Burlington, Vermont, during August 11–15, will soon be published by the Academic Press, Inc. The volume will be Supplement 1 of the journal *Radiation Research*, and has been edited by Douglas E. Smith, Argonne National Laboratory, Lemont, Illinois.

Erratum. In the communication entitled "Population Differentiation within Plant Species in Response to Soil Factors" in *Nature* of January 10, p. 129, the names against the curves in Fig. 1 should be interchanged.

PLANT PHYSIOLOGY IN CZECHOSLOVAKIA

By Prof. WALTER STILES, F.R.S.

At the invitation, and as the guest, of the Czechoslovak Academy of Sciences, I recently had the opportunity of visiting a number of plant physiological research establishments in Czechoslovakia. Since, so far as I know, few if any British plant physiologists have visited these institutions during the past twenty years, a brief impression of them may be of interest to Western readers.

In Prague, plant physiological research is carried out in two institutions, the Charles University and the Biological Institute of the Academy of Sciences. As most readers will know, the Charles University is one of the oldest in Europe, having been founded in the year 1348. For a time, in the latter part of the nineteenth and first part of the twentieth centuries, there were two universities in Prague, a Czech and a German, but since the War no such division of university administration any longer exists. The plant physiological department of the University, under the direction of Prof. S. Prát, is housed in the buildings of what was formerly the German University, which will be associated in the minds of older botanists with such well-known names as Molisch and Czapek. It is perhaps less well known that Sachs, who with reason has been regarded as the founder of modern plant physiology, worked for a time in Prague. These buildings are now sixty years old, but are spacious and well equipped, and the fine library with its large collection of pamphlets happily survived the German occupation although, unfortunately, the index of these was destroyed. Here much research is in progress under Prof. Prát's direction, as is indicated by the considerable body of publications which have appeared from his department during the past twelve years. Of work being carried out at present, particular attention is being given to the absorption of humic substances and their influence on plant metabolic processes. As botanists in Britain will know, a large collection of pure cultures of algae was made in Prague by Prof. E. G. Pringsheim and a collection of them was instituted in Cambridge during his residence there. Although many of his original cultures were lost to Prague after his departure from that city, others have been added and there is now maintained in the plant physiological department of the Charles University a large collection of cultures, not only of algae, including Cyanophyceae, but also of liverworts and mosses.

In the chair at the Charles University, Prof. Prát succeeded Prof. B. Němec, whose plant physiological researches in many fields won him a world-wide reputation half a century ago. It was a particular pleasure to me again to meet Prof. Němec and to be able to report to the many admirers of his work that in his eighty-sixth year he is hale and hearty and alert. To commemorate his eighty-fifth birthday in March 1958 a memorial volume entitled "Studies in Plant Physiology" was produced by the Czechoslovak Academy of Sciences and in which twenty-four distinguished botanists from many countries, including the United States, France, Holland, West Germany and Yugoslavia, as well as Central and Eastern European countries, contributed. It is interesting to note that among those paying tribute to Prof. Němec in this way was another veteran plant physiologist, Prof. W. J. V. Osterhout.

The Institute of Biology of the Czechoslovak Academy of Sciences has been so called since 1952, when the Academy was constituted; actually the building dates from 1926, having originally been devoted to research in agronomy and phytopathology. During 1950–52 it housed the Central Institute of Biology and Central Institute of Chemistry. The Institute is under the direct auspices of the Academy and is a purely research institution under the direction of Dr. I. Málek. Not only plant physiology but other experimental aspects of biology are dealt with here; these include microbiology, phytopathology, parasitology, radiobiology and electron microscopy among others. About a hundred research workers are engaged in investigations in the Institute. Among research projects of interest to plant physiologists are investigations on the relations between osmotic value and water deficit, cytochemical researches on mitochondria and their relation to plastids, and bud development in relation to the season of maturity and biennial bearing. Although the present buildings impress one as modern and very well equipped, new buildings for the purpose of biological research are being built.

In Brno, plant physiological work is in progress in two institutions, the laboratory for plant physiology and anatomy of the University and the Botanical Institute of the Technical University. In the former, under the direction of Prof. V. Rypáček, several researches of interest to plant physiologists are in progress. Among these may be mentioned the investigation of the growth and action of a number of wood-destroying fungi, including their effect on the composition of the attacked wood, the action of humic acid on the growth of plants, and the effect of one plant on another, with particular reference to the influence of couch grass on wheat, an effect which appears to be very striking. In the Technical University, Prof. R. Dostál, whose first work on correlation was published fifty years ago, many years before the word auxin had even been thought of, is still working enthusiastically on problems of correlation. Here, in the city where Mendel lived and worked, I was pleased to visit the little monastery garden where he carried out his pioneer experiments. In the garden is a stone with an inscription in Czech, German and French recording the fact that here Mendel carried out his experiments.

In Bratislava, the capital of Slovakia, scientific interests are in the care of the Slovak Academy of Sciences, while at the Comenius University plant physiology is in the charge of Prof. L. Pastýrik. The plant physiological laboratory here dates from 1936, and it is interesting to note that it was at first under the direction of Prof. B. Němec. Here a main plant physiological interest is in the mineral nutrition of plants. Thus, work has recently been published on the movement and accumulation of mineral nutrients in the xylem and phloem of apple and pear trees and on the dependence of the metabolism of tobacco leaves on micro-nutrients.

The site has been cleared in Bratislava for a new institute which will house plant physiology. If this is equal in quality to the fine Institute of Biochemistry maintained by the Slovak Academy of Sciences, plant physiology will be well provided for in the capital of Slovakia.

The time at my disposal did not permit me to visit Košice in the south-east of Slovakia ; but I was given to understand that work of high quality on photosynthesis was in progress there.

Archæology, although outside my range of special knowledge, is within my field of general interests, and I was therefore pleased to visit the Archæological Institute of the Slovak Academy of Sciences at Nitra. This is appropriately housed in Nitra Castle and is provided with a fine library and laboratories well equipped on modern lines.

I cannot conclude this brief account of my impressions of plant physiological activities in Czechoslovakia without expressing my indebtedness to the Czechoslovak Academy of Sciences and the Slovak Academy of Sciences for the excellent arrangements made for my visits to the various research institutions and of my deep appreciation of the friendliness and kindness I experienced from everyone I met in Czechoslovakia and particularly from my plant physiological colleagues in Prague, Brno and Bratislava and from the director and staff of the Archæological Institute in Nitra.

SELF-REGULATION IN LIVING SYSTEMS

SYMPOSIUM AT OTTAWA

A SHORT symposium on self-regulation in living systems, organized by Dr. D. K. C. MacDonald, was held at the laboratories of the National Research Council in Ottawa on October 20. About twenty-five representatives of a wide range of professions—biophysics, electrical engineering, mathematics, neurology, philosophy, physics, psychology and zoology—took part in the symposium and an attempt was made to establish some common ground within these fields through problems of interest to all. This first meeting was necessarily of an exploratory nature.

The problem of self-regulation in living systems may be considered on two levels. First, the details of self-regulation within a given animal (homeostasis) and its perception of and reaction to the external world, both of these tasks being handled by the nervous system. This might be termed the microscopic picture. Second, there is the relation of animal populations with their surroundings (ecology)—or the macroscopic level. In both cases the processes involved are analogous to those found in the inanimate control systems of physics and engineering.

Papers outlining our knowledge of the nervous system were read by Dr. B. Delisle Burns and Dr. P. M. Milner, both of McGill University, and by Dr. E. A. Atack (Ottawa). A nerve cell, or neurone, when stimulated sufficiently, will transmit the signal to other neurones which are connected to it. This period of activity is followed by a refractory period, or 'dead-time', and thus the mode of action is analogous to a Geiger counter tube. In the control centres of an animal the neurones appear to be connected together in an unorganized fashion (a useful genetic property) to form a 'nerve net'. A mathematical treatment of the propagation of signals within such nets has been given by Beurle (1956). Nerve nets in the lower control centres are responsible for self-sustaining processes within the body. For example, the control of respiration is due to nets located within the brain stem. The processes of learning and memory appear to be associated with the nerve nets located in the cerebral cortex or outer layer of the brain. It is supposed that repeated applications of the same stimulus produce some change in the neurones affected by it (or in their connexions), and thus pathways within the nets become established. Similarly, an association of pathways may be built up. Thus memory seems to be due to combinations of neurones. Since, in man, there are about 10^{10} neurones involved the total possibilities are obviously enormous—in marked contrast to insects (where the relevant number is of the order 10^3) which nevertheless show an apparently complex behaviour. Cerebral malfunctioning may affect the internal workings of the body or show external effects. Thus analysis of pathological symptoms will suggest the site of a particular disturbance.

A particular aspect of the nervous system, the handling of visual information, can be readily demonstrated. Dr. A. Burton (University of Western Ontario) presented some rather sophisticated optical illusions exhibiting : (1) a biochemical cycle in the retina, (2) adaptation in the cerebral cortex, and (3) the subjective nature of much visual information.

There was, inevitably, a discussion on the relation of computing machines to the brain, initiated by Dr. D. K. C. MacDonald (National Research Council). The ability of present-day computors to make decisions involving some long-term strategy was emphasized. It was suggested in the discussion that a distinction between an animal and a machine could be made in terms of the responses of an animal at 'higher' levels (for example, pleasure, pain) and by the fact that an animal does not always appear to behave logically.

Some large-scale aspects of self-regulation were summarized by Dr. Max Dunbar (McGill University). Particular ecological systems were discussed and it was concluded that a non-oscillatory state provides optimum conditions for survival. (Indeed, violent oscillations may prove lethal to a particular species.) Some animals contribute to stable conditions by relatively inefficient breeding habits and by tendencies or conditions leading to a high death-rate. Relations between population-levels of various species are often analogous to feedback system characteristics. It seems, therefore, that ecological systems may show an apparent ability to 'learn'. Of interest here is J. Z. Young's description of the brain as an ecology of nerve cells.

The freely ranging discussion provoked by all the papers indicated that the gaps between the various disciplines had certainly been narrowed. It is hoped that a further symposium on a similar topic will be organized in the near future. An informal report of this symposium is in preparation. DOUGLAS L. MARTIN

THE INDIAN AGRICULTURAL RESEARCH INSTITUTE

THE Indian Agricultural Research Institute has been accorded the status of a university with power to confer the degrees of M.Sc. and Ph.D. in all the important aspects of agricultural science. The new Postgraduate School was formally inaugurated on October 6, 1958, by Shri Ajit Prasad Jain, Minister for Food and Agriculture in the Government of India.

The Institute is popularly known as the Pusa Institute, after a small village called Pusa in Bihar, where it was first established as the Imperial Agricultural Institute in 1905 with a gift of £30,000 from Mr. Henry Phipps, an American philanthropist. It has now developed into a centre of considerable size, providing facilities for training and research in almost all the important branches of agricultural science. These various activities are carried out by its seven Divisions, covering, respectively, agronomy, botany, mycology and plant pathology, entomology, horticulture, soil science and agricultural chemistry, and agricultural engineering, under the over-all supervision of the director, Dr. B. P. Pal. All the Divisions are housed separately in spacious buildings, furnished with modern equipment, and each is staffed with teachers and specialists in the appropriate field.

The Institute has inherited a great tradition of agricultural research and education, going back to the work of Leather in agricultural chemistry, of Butler on fungi and fungal diseases of plants, of Maxwell-Lefroy and Fletcher in cataloguing and combating insect pests, of the Howards in breeding the early 'Pusa' wheats, and of Venkataraman in breeding Coimbatore canes. High among the recent achievements are the breeding of *NP* ('New Pusa') wheats, of which *NP* 710 and *NP* 718 combine considerable resistance to rust with high resistance to loose smut. An outstanding success is the breeding of *NP* 809 wheat for the hills, uniting resistance to the three rusts. Among other contributions of note are the building up of a fine milch herd of the Sahiwal breed; the construction of schedules for the control of some important diseases of sugar cane; and the improvement of techniques of breeding parasites for the biological control of some insect pests of crop plants.

The Library, which receives more than a thousand periodicals and possesses almost all the important publications on agricultural science, is considered to be the best agricultural library in the East, and caters for the needs of agricultural scientists all over India. Other assets of the Institute include collections of varieties of crop plants from which the plant breeder can select the genes for his breeding work; the National Collection of Insects; the Herbarium Cryptogramme Indiae Orientalis, one of the best assemblages of fungi in the East; and the Indian Type Culture Collection.

The archives of the Institute show that, from its inception in 1905, it was meant to be a central organization of postgraduate teaching. In 1923, two-year postgraduate courses leading to the award of the diploma of the associateship of the Imperial Agricultural Research Institute were instituted, offering limited facilities to students in specialized fields, without, however, offering any definite courses. In 1945 the system of training was thoroughly reorganized, courses and syllabuses were prescribed and a system of examinations introduced. The diploma awarded is comparable with the M.Sc. degree of a university.

The present decision to provide the Institute with a Postgraduate School is a natural step in fulfilling the objects which the planners of the Institute had in view. The recommendations of the Indo-American team on agricultural research and education were instrumental in giving shape to the ideals of its founders. The Postgraduate School, which will mainly be responsible for carrying out the teaching programme, has come into existence with the generous aid of the Rockefeller Foundation. The aim is to train leaders for the programme to improve agricultural technology in India.

The students will have a large number of courses to choose from, including crop husbandry, soil and water management, agricultural extension; plant breeding and genetics, cytogenetics and plant physiology; taxonomy, ecology, toxicology, parasitology, and physiology of insects; pomology, olericulture, fruit and vegetable preservation; mycology and plant pathology; soil science and agricultural chemistry; and agricultural engineering. Courses in experimental statistics will be offered in co-operation with the Indian Council of Agricultural Research.

Provision has been made, for the present, for admitting each year up to one hundred students for the M.Sc. degree and fifty students for the Ph.D. degree.

B. P. PAL

THE EMPLOYEE'S POINT OF VIEW

IN the middle nineteen-thirties, the National Institute of Industrial Psychology was asked by a large and well-known company to help in solving a staffing problem. The company's employment policy was progressive, and reasons for a very high rate of leaving were obscure. It was arranged to take the (then) unorthodox step of inviting employees to come, in confidence, to the Institute's investigator to give suggestions for improvements in their working conditions or to mention features of them which they would like to see changed. These interviews had far-reaching results; from their success stems a technique which has been fruitfully applied in the United Kingdom to the diagnosis of many working situations, in industry, shops and offices, hospitals and voluntary organizations. It brings to the study of people in their working environment, and particularly in relation to difficulties they experience, a special combination of human understanding with scientific discipline.

The core of the method consists in confidential, undirected interviews with a sample of employees of all levels; the interviews are conducted by an impartial investigator who is not on the staff of the

organization, and in whose freedom from bias all concerned may have confidence.

After many years of experience, during which the Institute's technique in this work was progressively improved, there was developed a standard system for classifying subjects raised in such interviews. It provided convenient, ordered categories to which could be assigned remarks relating to any aspect of working life, and it was intended to facilitate future study of the accumulating material.

Dr. Isabel Blain has now made a pilot study of results collected and reported by these methods within a recent two-year period (Comments on the Job. Nat. Inst. Indust. Psych., Rep. 13, 1958). The data came from six firms; all were manufacturing companies, and apparently had little in common save their concern over some aspect of their organization or operation, to improve which they had invited the Institute's help. They differed in size of pay-roll, form of ownership, geographical position, age, history and tradition, arrangements of hours and shifts, degree of trades union influence, amenities, welfare provisions, and physical working conditions. The purpose of the study was to see whether, in spite of these differences, similarities would be found in the spontaneous remarks made by 1,678 factory staff and operatives.

Some of the salient points which emerged showed a surprising degree of similarity in each of the firms investigated. Thus, planning and control procedures, timing, time standards and time allowances, maintenance and stores arrangements were common topics of complaint.

Practice and policy relating to training, promotion and transfer were criticized, sometimes through ignorance, sometimes justifiably, due to acknowledged defects; but there were also instances where approval was expressed of company action in these fields.

On matters of pay, men complained more frequently than women about the amounts earned; but the greatest body of critical comment related to financial incentive schemes and to differentials.

In every company there were remarks about the inadequate definition of responsibility and authority; similarly, poor liaison between shifts or between departments was commonly mentioned; there were also frequent complaints about lack of information from management.

PATTERN OF SYNTHESIS OF DEOXYRIBONUCLEIC ACID IN *BACILLUS CEREUS* GROWING SYNCHRONOUSLY OUT OF SPORES

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VARYING degrees of synchrony of bacterial cell division have been achieved by prior subjection of the cell population to chilling[1], cycles of chilling and warming[2–5], to starvation followed by replenishment[6,7] and by separation of the cells into a homogeneous group by fractional filtration[8]. In all such cases synchrony "is initiated by a phase of recovery from imposed stress and unbalance"[6] and in some there is evidence that interference with the synthesis of deoxyribonucleic acid is the critical feature[9]. It has already been shown that the initial duplication of the chromatin body of synchronously germinated spores (*B. megaterium* and *B. cereus*) is accompanied by a linear synthesis of deoxyribonucleic acid[10]. But, as no cellular division occurred prior to these doublings, no data were available regarding the relationship between synthesis of deoxyribonucleic acid and the normal division cycle. Such has now been obtained from a combined cytological and chemical study of *B. cereus* in which synchronous germination of spores was followed by two successive periods of synchronous cell division.

Uniform batches of spores were harvested from either the agar medium of Howie and Cruickshank[11] or a fluid medium (glutamine–casein–yeast) developed for the study of synchronous spore formation[12]. Spores were washed free of all traces of cell debris by eight cycles of differential centrifugation from water. Spore counts were made on appropriate dilutions of the final clean suspension.

The germination medium used was similar to that already described[10]. Spores sufficient to give a final concentration of $0{\cdot}6 \times 10^9$/ml. were inoculated below the surface of the medium, which had been warmed to 37° C. Aeration by shaking was begun immediately, and after 3 min. a drop of tri-*n*-butyl citrate was added to counteract foaming.

Cells centrifuged from rapidly chilled samples were washed in quick succession with ice-cold bicarbonate buffer, 50 per cent ethanol in buffer and absolute ethanol. Following disruption of the cells with glass beads (Ballotini No. 12) in the Mickle[13] tissue disintegrator, deoxyribonucleic acid was extracted by the Schmidt and Thannhauser procedure[14] and estimated by the Dische reaction[15]. At each time period of analysis, the living cells were examined in the phase-contrast microscope and osmium-fixed impression smears stained by an azure *A*–Feulgen procedure[16] were examined under the light microscope.

In order to obtain good synchrony through the first two divisions of the emergent cells, it was considered necessary that 95 per cent of the spores lose refractility and stain deeply with crystal violet (that is, begin germination) during a 1-min. interval commencing 1¼–2 min. following inoculation. Occasionally this degree of synchrony could be obtained with fresh spores. In such cases prior activation with sublethal heating[17] (70° C. for 15 min.) did not improve the degree of synchrony. However, heat treatment usually decreased the response time of germination and made synchrony more readily attainable. It should be stressed that the subsequent pattern of synthesis of deoxyribonucleic acid was the same whether or not the spores were activated by heat.

In Fig. 1, the content of deoxyribonucleic acid of a culture is plotted as a function of the initial number of spores from resting spores (zero time) to the end of the second division of the emergent cells. The rise associated with the initial duplication of the spore chromatin body (Fig. 1, up to 60 min.) has been described earlier[10]. In three separate experiments, no alteration in the rate of synthesis of deoxyribonucleic acid followed this initial doubling of the acid and duplication of the nuclear body. It could be seen from the nuclear-stained preparations and from the phase-contrast appearance of the living cells that the first cell division began about 72 min. after inoculation (Fig. 2) and was complete some 6–8 min. later. Direct cell counts at these times confirmed these observations.

At the beginning of division, each cell contained $2\frac{3}{4}$ times the average amount of deoxyribonucleic acid found in the original spore. At the end of division this had risen to 3 times, so that each new cell now contained $1\frac{1}{2}$ times the spore amount of deoxyribonucleic acid. After division, synthesis again continued in a linear fashion but at a slightly greater rate than before, until each new cell once more entered division with $2\frac{3}{4}$ times the spore-level of deoxyribonucleic acid (Figs. 1 and 2). Duplication and separation of the nuclear bodies thus occur midway between cell divisions and during a period of continuing synthesis of deoxyribonucleic acid (Fig. 2).

Since the deoxyribonucleic acid content of a *Bacillus* cell may vary from 1·5 to 2·8 times the spore-level, the 'average' cell in an asynchronous population would contain approximately twice the spore amount of deoxyribonucleic acid[12,18]. Furthermore, the average amount of acid per spore has been found to be remarkably constant for any given species and not altered by variations in the composition of the growth medium[19].

A slight decrease in synthesis of deoxyribonucleic acid during the period of cell division is indicated by the results obtained from samples taken at 10-min. intervals (Fig. 1). The slope of the rise of deoxyribonucleic acid before the first division is 1·4, while after the division it is 1·8 (Fig. 1). A more pronounced decline in the rate of synthesis of deoxyribonucleic acid was encountered during the second division when another sampling, 5 min. after the 100 min., was possible.

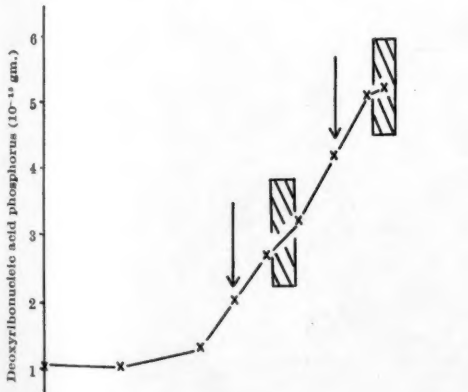

Fig. 1. Deoxyribonucleic acid-phosphorus expressed on the basis of the initial spore count, during the synchronous growth of *B. cereus* from spores through two cell divisions (hatched areas). The arrows indicate the period when each cell contained two fully separated chromatin bodies and twice the spore content of deoxyribonucleic acid

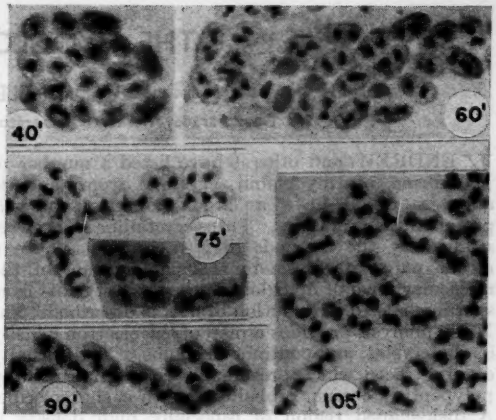

Fig. 2. Changes in nuclear morphology during synchronous growth of *B. cereus* out of germinated spores. Osmium-fixed smears, azure *A*–Feulgen. By 40 min. the spore coats still cover the growing cells but the single nuclear bodies have begun to elongate. At 60 min. the deoxyribonucleic acid has doubled and each cell in proper focus shows two separated nuclear bodies; shed spore coats are also present. By 75 min. the first cell division is proceeding and each nuclear structure is growing into two again. By 90 min. each daughter cell once more contains two separated nuclear bodies, and by 105 min. the second division is under way with the nuclear bodies partly separated like those at 75 min. (× *c.* 2,700)

Cohen's[7] studies with a thymine-requiring *E. coli* synchronized by starvation and replenishment of thymine suggested that doubling of the deoxyribonucleic acid occurred prior to cell division and that during division synthesis of the acid ceased. Lark and Maaløe[2] found that in heat-treated cultures of *S. typhimurium* doubling of the acid was followed by nuclear division. However, in contrast to the findings of Cohen[7], cell division overlapped the period of synthesis of deoxyribonucleic acid. The results reported here, in which synchrony is achieved without recourse to artificial treatment, indicate that during the growth-cycle, synthesis of deoxyribonucleic acid is continuous between, but diminished in rate during, cell division.

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THE MYOGLOBIN MOLECULE

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KENDREW and others[1] have listed a number of forms of myoglobin crystals from aquatic animals, which have a large proportion of this protein in their muscles. These crystalline forms were studied by the methods of X-ray analysis. In a recent paper[2], a three-dimensional solution of the molecular form of myoglobin in type *A* crystals from sperm-whale to a resolution of 6 A. is described. The X-ray analysis provides a map of the electron density in the crystal, and continuous chains of high density can be traced which presumably represent coiled-up polypeptide chains, probably one to each molecule. A disk-shaped region of especially high density is identified with the haem group. The molecules so outlined are separated by extended regions of uniform density which must be attributed to the liquid in the intermolecular spaces. This form of the convoluted chain is illustrated in Fig. 2 of Kendrew's paper[2].

I have been engaged on an X-ray study of myoglobin from the common seal (*Phoca vitulina*), first characterized by Kendrew and others[1] as type *C*. This forms monoclinic crystals, space group $A2$, $a = 57{\cdot}9$ A., $b = 29{\cdot}6$ A., $c = 106{\cdot}4$ A., $\beta = 102° 15'$, with four molecules per unit cell. The method of isomorphous replacement introduced by Perutz[3] has been used, the attached heavy-atom groups being $AuCl_4'$, HgI_4'' and *p* - chloro - mercuri - benzene sulphonate. These groups were introduced by methods analogous to those used by Kendrew and others[2] in type *A*. A two-dimensional projection of the crystal density on the *b*-plane has been obtained to a resolution of 4 A., and is shown in Fig. 1.

The present communication describes an attempt to explain Fig. 1 in terms of Kendrew's three-dimensional model. If the myoglobin molecule from sperm-whale is closely similar to the myoglobin molecule from seal, it should be possible to take the sperm-whale myoglobin molecule, re-orientate it in a suitable way, project its density on to a plane, and obtain a match with the density map of Fig. 1. Allowance must, of course, be made for the overlap of neighbouring molecules. As will be shown, it is possible to make this comparison and the fit is remarkably good.

I have been guided in making the comparison by two features of the molecule. In the first place, the Fourier map in Fig. 1 shows regions of high density marked *H*, and there is a strong *a priori* probability that these are the haem groups. In the second place, the results of Ingram and others[4], based on electron spin resonance methods, indicate the orientations of the normals to the haem groups in both the sperm-whale and seal myoglobin crystals. In searching for the right direction in which to make the projection, one therefore has a fixed point in both molecules, the haem group, and these must be brought into superposition. The normals to these haem groups must also be brought into alignment, so that the only variable left is the angle through which the molecule must be turned around the haem-group normal.

A first approximation to the correct orientation was made with the help of a solid model like that shown in the paper by Kendrew *et al.*[2]. Several orientations for the model were tried and in each case the total

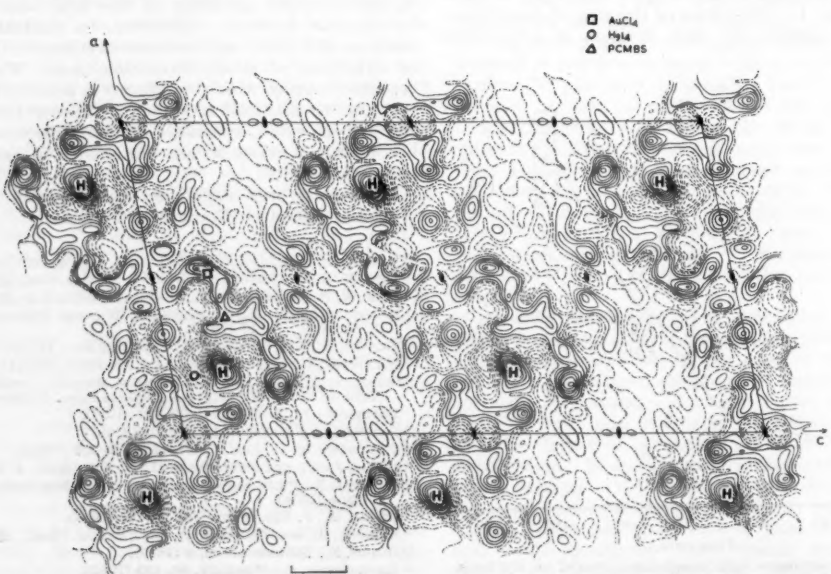
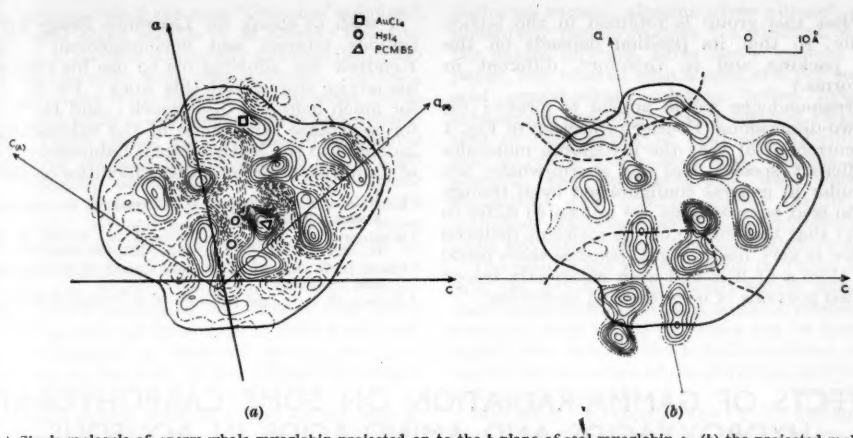


Fig. 1. Projection on the *b*-plane of the electron density distribution in the cell of seal myoglobin, seen at a resolution of 4 A. □, $AuCl_4$; ○, HgI_4; △, *p*-chloro-mercuri-benzene sulphonate



(a) (b)

Fig. 2. (a) Single molecule of sperm-whale myoglobin projected on to the b-plane of seal myoglobin ; (b) the projected molecule with overlap from the molecules related by the screw axes

thickness of chain as shown in that figure was projected on to a plane. When a promising approximate match to Fig. 1 was obtained, it was further explored by summing up the actual electron densities in the appropriate direction. A detailed description will appear elsewhere.

Fig. 2 (*a*) shows this summation for a single molecule projected in a direction which was found to give the best agreement. The axes of the seal myoglobin crystal are shown as heavy lines, the projected axes of the sperm-whale myoglobin crystal as light lines. In the cell of the seal myoglobin crystals there are screw axes at $a = 0$, $c = 0$; $a = \frac{1}{2}$, $c = 0$; $a = 0$, $c = \frac{1}{2}$, $a = \frac{1}{2}$, $c = \frac{1}{2}$; so to compare the results one must allow for the fact that two molecules, related by a screw axis, will overlap. The superposition is shown in Fig. 2 (*b*), where for simplicity contours of positive density have alone been drawn, and the outline of the molecule as deduced by Kendrew is indicated. Fig. 3 is another version of Fig. 1, the *b*-axis projection of seal myoglobin. In this version, only terms to a resolution of 6 A. have been included, and only positive contours drawn, so as to make the comparison with Kendrew's results more direct.

The correspondence is remarkably close, as will be seen by comparing Fig. 2 (*b*) and Fig. 3. The outlines of the molecules are drawn to facilitate the comparison. All the high-density features obtained by projecting Kendrew's solution are faithfully reproduced in the *b*-projection of the seal myoglobin crystal. The haem groups, seen edgewise in the projection, appear as dense regions in corresponding places. Further, the Au and HgI_4 group used in both analyses lie in corresponding positions in the two projections, Fig. 2 (*a*) and Fig. 1, indicating that they are attached to the protein molecules at the same points. (This is not true, however, of *p*-chloromercuri-benzene sulphonate, but there is some

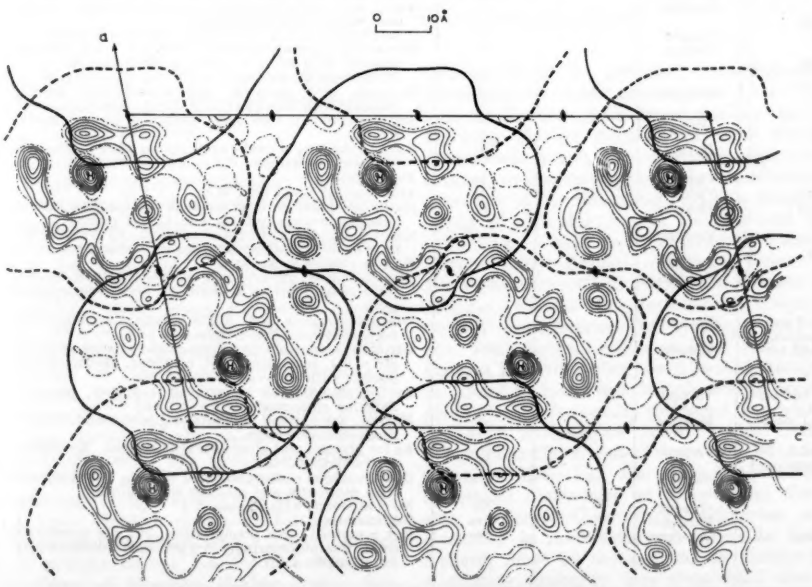


Fig. 3. Electron density projection of seal myoglobin seen at a resolution of 6 A.

evidence that this group is retained in the lattice interstitially, so that its position depends on the molecular packing and is, therefore, different in different forms.)

This correspondence would appear to prove: (*a*) that the two-dimensional Fourier projection of Fig. 1 is nearly correct; (*b*) that the myoglobin molecules in two different species, seal and sperm-whale, are closely similar in general configuration even though their amino-acid compositions are known to differ in details; (*c*) that the outline of the molecule deduced by Kendrew is very nearly right, because there could not be so close a fit if it had been incorrectly traced and included portions of neighbouring molecules.

I wish to thank Sir Lawrence Bragg for his continuous interest and encouragement; Dr. J. C. Kendrew for allowing me to use his results and for his advice throughout this work; Dr. D. C. Phillips for much help and discussions; and Dr. V. C. Shore for assistance with some of the calculations. I am indebted to the Mathematical Laboratory, University of Cambridge, for computing facilities on the EDSAC.

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EFFECTS OF GAMMA-RADIATION ON SOME CARBOHYDRATES, HYDROXYACIDS AND AMINO-ACIDS IN AQUEOUS SOLUTIONS

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IN an investigation of the effect of γ-radiation from a 200-c. cobalt-60 source on dilute (0·1 per cent) aqueous solutions of some carbohydrates, hydroxyacids and amino-acids we have found that in the absence of oxygen (that is, *in vacuo* or under nitrogen), radicals[1] derived from these compounds exhibit a strong tendency to dimerize (irradiation dose $5{\cdot}5 \times 10^{19}$ eV. ml.$^{-1}$) and that prolonged irradiation produces polymeric materials. Acidic non-dialysable polymers have been isolated (see Table 1), which

Table 1. Irradiation of Carbohydrates, Hydroxy- and Amino-acids in Aqueous Solution

Solute irradiated	Conditions	Polymer formation indicated by dialysis	Polymer formation indicated by cetavlon	Other compounds formed, remarks, etc.	Periodic acid treatment (see text)
Maltose	Vacuum	Yes	Yes	Glucose, gluconic acid, maltobionic acid, *et al.*	
Glucose	Vacuum	Yes	Yes	Gluconic acid, 2-oxo-D-arabino-aldohexose, 2-oxo-D-arabino-hexonic acid, arabinose, *et al.*	
	Oxygen	No	No	Gluconic acid, *et al.*	
	Nitrogen	Yes	Yes	As vacuum system	
Glycollic acid	Vacuum	Yes	Yes	Glyoxylic, tartaric, oxalic and formic acids, formaldehyde and CO_2	Yes
	Oxygen	No	No	As for vacuum system, but only traces of tartaric acid	
Glyoxylic acid	Vacuum	—	—	Oxalic acid, reducing acidic dimer and trimer. Dimer may be dihydroxytartaric acid	Yes
	Oxygen	—	—	Oxalic acid, no other non-volatile products detected	
Tartaric acid	Vacuum	—	—	Non-acidic reducing compound with $R_T = 1{\cdot}6$, reducing material with $R_T = 1$. Main product had $R_T = 0{\cdot}3$, $M_T = 1{\cdot}0$ ('dimer'?)	Yes
	Oxygen	—	—	Mesoxalic acid, glyoxylic acid, considerable reducing material with $R_T = 1$	Yes
Oxalic acid	Vacuum	—	—	Small amounts of a reducing compound formed, having $R_T = 0{\cdot}6$	
	Oxygen	—	—	Considerable loss of oxalic acid, but no other non-volatile compounds detected	
Lactic acid	Vacuum	Yes	Yes	Not examined	
Gluconic acid	Vacuum	Yes	Yes	Arabinose, arabonic acid, *et al.*	
Mandelic acid	Vacuum	?	?	Heavy precipitation from aqueous solution, CO_2 formed. Precipitate contains C_6H_5- and .COOH groups	
Formic acid	Vacuum	—	—	Mesoxalic acid, dihydroxytartaric acid and probably tartaric acid. Streaking between $R_T = 0$ and 1·5	Yes*
	Oxygen	—	—	No non-volatile products	
Glycerol	Vacuum	—	—	Glyceraldehyde, glyceric acid, at least two non-reducing compounds behaving as hexitols. Traces non-reducing acids	
Glycollic acid and glyoxylic acids†	Vacuum	—	—	Dihydroxytartaric acid. Slight uptake of bromine water, suggesting some dihydroxymaleic acid	
Glycollic† and tartaric acids	Vacuum	—	—	Glyoxylic acid, slightly reducing acidic component with $R_T = 0{\cdot}7$, suggesting a 6-C co-dimer. Reducing compounds with $R_T = 1$.	
Glyoxylic† and tartaric acids	Vacuum	—	—	As for glycollic and tartaric acids system, but more reducing compounds at $R_T = 1$ and 0·7	
Glycerol and glyceraldehyde†	Vacuum	—	—	Hexonic acids, small amounts of glyceric acid. Hexose production uncertain	
Glycerol and 1 : 3-dihydroxyacetone†	Vacuum	—	—	As for glycerol and glyceraldehyde system. Ketohexose production doubtful	
Glycine	Vacuum	—	Yes	Compounds or compound with $R_{glycine} = 0{\cdot}5$ detected with ninhydrin and alkaline silver nitrate	
	Oxygen	—	No	No compounds with $R_{glycine} < 1$	
Alanine	Vacuum	—	Yes	Not examined	
Phenylalanine	Vacuum	—	Yes	Not examined. No precipitation, but the freeze-dried solute was only sparingly (0·2 per cent) soluble in water (cf. mandelic acid)	

* Forms glyoxylic and oxalic acids.
† Indicates the component in mixed systems which was the more readily destroyed by radiation.

gave precipitates with 2 per cent 'Cetavlon' solution[2], the precipitates being soluble in *M* sodium chloride. The presence of oxygen drastically reduced dimerization, and no polymers were then detected. Instead, oxidation products were formed by processes which involved considerable C—C bond scission and decarboxylation. These effects can be readily explained by the radicals initially produced from the solvent causing hydrogen abstraction from the organic solute, thereby forming an organic radical[3]. *In vacuo* or under an atmosphere of nitrogen these radicals may join together or undergo saturation by the addition of a solvent radical. In the presence of oxygen, the gas readily adds on to the organic radical to yield a peroxy-radical, which may react with radicals[4] present in the system to yield a molecule in which, ultimately, a hydroxy group has been substituted on to the site of the original hydrogen abstraction.

The emphasis in this work has been on the radical addition reactions occurring *in vacuo*, including reactions occurring in solutions containing more than one solute when dimers are formed by linking of the various radicals. The glucose and glycollic acid systems have been examined, and in the latter case a complete mass balance in the presence and absence of oxygen has been obtained[1]. Polymeric materials have been isolated as indicated, but the evidence for compound formation is based on chromatographic and ionophoretic analysis. The mobility values quoted, R_T and M_T, are the chromatographic (propionic acid/*n*-butanol/water—3 : 6 : 4 v/v) and ionophoretic (0·2 *M* acetate buffer, *p*H 5·0) mobility values respectively, relative to tartaric acid. The spray reagents used were aniline hydrogen phthalate[5] (reducing sugars), alkaline silver nitrate[6], and chlorophenol red[7] (acidic groups). In addition, in some cases the solute mixture, after being spotted on to the paper, was treated with a spot of 5 per cent periodic acid pentahydrate solution before irrigation and subsequent spraying[8]. This method causes tartaric acid to yield glyoxylic acid and dihydroxytartaric acid to yield oxalic acid, etc. In the amino-acid systems, the chromatograms were sprayed with ninhydrin[9] and alkaline silver nitrate[6], and the mobilities expressed as $R_{glycine}$ relative to glycine using the propionic acid/*n*-butanol/water solvent.

The results are shown briefly in Table 1, and indicate the potentials of mixed solute irradiations in vacuum for forming radical addition products, and the readiness with which polymers can be formed. It is hoped that further work will elucidate more thoroughly the structure of the polymers and the addition compounds formed.

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SOME SOUTH AFRICAN STONE AGE CULTURES

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Statistical Analysis of the South African Later Chelles–Acheul and Earlier Fauresmith Cultures

In South Africa our knowledge of the Earlier Stone Age is based on pioneer work that yielded the framework of stratigraphy and broad typo-technological outline of the main prehistoric cultures. Pioneer research regarded the Fauresmith Culture as well separated typologically, technologically and stratigraphically from its ancestor, the Chelles–Acheul. In the Vaal River Basin the South African Chelles–Acheul Stages III–V industries, here described as Later Chelles–Acheul, are found in the later aggradations of the Younger Gravels and overlying calcified sands with a predominantly Middle Pleistocene fauna[1], while the Earlier Fauresmith lies on the surface of the calcified sands and in the Youngest Gravels of the Vaal tributaries[2].

Recent excavations at two Transvaal sites, the Cave of Hearths near Potgietersrus and Wonderboom near Pretoria, have yielded important Earlier Stone Age industries originally classified as Later Chelles Acheul on a non-statistical basis[3,4]. Subsequent study of the Cave of Hearths Earlier Stone Age fauna showed it to be of Later Pleistocene age (Cooke, H. B. S., personal communication), that is, considerably more recent than the Vaal Chelles–Acheul fauna. Industries similar to the Cave of Hearths Earlier Stone Age were found in Later Pleistocene gravels at open sites near the cave. This dating evidence, apparently conflicting with the typology of the industries, led to a detailed statistical study of both the Cave of Hearths and Wonderboom industries, which were statistically compared with Later Chelles–Acheul industries from Vaal Middle Pleistocene gravels at Riverview Estates and Canteen Koppie. It was then found that, despite very close overall resemblances in typology and technology, the Vaal Later Chelles–Acheul and Wonderboom–Cave of Hearths series could be statistically separated, in terms of hand-axe length–width proportions and proportions of dorsally prepared quadrilateral flakes. A Later Pleistocene gravel series from Rooiberg, geographically situated between Wonderboom and Cave of Hearths, was found to have the same statistical characters as those from the latter two sites. Clearly these three industries, all originally classified in non-statistical terms as Later Chelles–Acheul, must be re-classified as Earlier Fauresmith, a culture probably less than half the age of the Later Chelles–Acheul.

Hand-axe length–width proportions. The use of this index in the South African context was suggested by McBurney's distinction between European Acheul and Mousterian hand-axes[5].

In the latter valuable study, McBurney was able to show that Acheul hand-axes were considerably narrower than Mousterian specimens, the Acheul length–width percentage varying from 57·38 to 61·53, while the Mousterian percentage ranges from 69·40 to 77·27.

The South African percentages are as given in Table 1.

Table 1. Hand-axe Length–Width Percentages

Culture	No. of observations	Average length–width (per cent)
Vaal Later Chelles–Acheul		
Riverview Estates Younger Gravels	56	54
Transvaal Earlier Fauresmith		
Cave of Hearths Bed 3	62	65
Wonderboom	52	65
Rooiberg Youngest Gravels Earlier Group	45	58
Rooiberg Youngest Gravels Later Group	30	63

These figures indicate that the Vaal Later Chelles–Acheul hand-axes, typologically very similar to Transvaal Earlier Fauresmith, are nevertheless narrower, at the sites listed, just as European Acheul hand-axes appear to be narrower than Mousterian hand-axes.

Quadrilateral flakes with prepared dorsal surfaces. The term 'quadrilateral flake' has been defined[6], and refers to flakes having a quadrilateral plan view. Quadrilateral flakes, like all flakes, may owe their shape either to deliberate or haphazard preparation of the dorsal surface. In Western Europe flakes with deliberately prepared dorsals are called 'Levallois' flakes, a term discontinued in Southern Africa following a decision by the Pan-African Congress of Prehistory in 1947[7]. The latter decision apparently confused the Levallois technique of dorsal preparation with the faceted platform technique, which is not necessarily an aspect of the Levallois technique.

Table 2. Dorsally Prepared Quadrilateral Flake Percentages

Culture	Total	Percentage dorsally prepared
Vaal Later Chelles–Acheul		
Canteen Kopje Younger Gravels	46	19
Transvaal Earlier Fauresmith		
Cave of Hearths Bed 3	225	48
Wonderboom	63	61
Rooiberg Youngest Gravels Earlier Group	39	56

The figures (Table 2) indicate a more extensive use of dorsal preparation technique in the Transvaal Earlier Fauresmith than the Vaal Later Chelles–Acheul, at the sites listed. The Rooiberg Youngest Gravels Later Group quadrilateral flake sample is too small for inclusion in Table 2.

Some differences in length dimensions of the hand-axe and quadrilateral flake classes in the Vaal Later Chelles–Acheul and Transvaal Earlier Fauresmith samples available may be seen, but these will be set out elsewhere with the full account of the investigation summarized in the present article.

Two main considerations emerge from this preliminary study. It is suggested that the Fauresmith Culture of the type area, Western Orange Free State and Northern Cape, has been defined on the basis of a late stage more clearly distinct from the Chelles–Acheul than its earlier stage as seen in the Transvaal. A broader definition of the Fauresmith Culture, on a statistical basis, is indicated. Secondly, the weakness of a non-statistical classification which failed to distinguish industries similar in typology and technology, but immensely different in age, has been shown, emphasizing the importance of statistical analysis in prehistory.

Parallels between the French Mousterian and Transvaal Earlier Fauresmith Cultures

Goodwin, in his original description of the Fauresmith Industry, noted the presence of a flake element showing close resemblances to the French Mousterian, which he attributed to the arrival of Mousterian influences in South Africa[8]. Burkitt[9] also directed attention to such similarities, and later workers have repeated these views. Both Goodwin and Burkitt based their opinions on material from the Fauresmith type area, namely, the Northern Cape and Western Orange Free State. Later, the Fauresmith Culture was recognized beyond the confines of the type area, while recent excavations in the Cave of Hearths in the Makapan Valley and Wonderboom near Pretoria have given adequate material for detailed examination of the culture in the Transvaal. No detailed comparison of the Fauresmith and French Mousterian was made until 1956, when I was able to carry out a brief comparative study generously financed by the Wenner Gren Foundation for Anthropological Research.

Intercontinental dating comparisons of Stone Age cultures are insecure, but it is significant that the French Mousterian culture falls within the European Upper Pleistocene[10], while the Earlier Transvaal Fauresmith belongs to the local Later Pleistocene, as seen in the Makapansgat Cave of Hearths fauna (Cooke, Dr. H. B. S., personal communication), suggesting a broadly equivalent position in the world time-scale. F. Bordes[11] observes at least six variants within the French Mousterian group, of which only two concern us here, the 'typical' Mousterian and Mousterian of Acheulean tradition. The typical Mousterian appears to be a variant of the Mousterian of Acheulean tradition, its typology consisting of similar flake classes without the higher proportion of hand-axes and cleavers found in the latter industry. Both industries are frequently found in different beds at the same site, such as Le Moustier and Abri Brouillard in the Dordogne.

With the kind permission of Mr. Harper Kelley, I was able to study the Abri Brouillard industries in the Musée de l'Homme, Paris. Peyroney and Bourrinet excavated Abri Brouillard in 1907, finding two superposed Mousterian beds overlain by a thin 'Aurignacian' horizon[12]. The large number of irregular artefacts and waste fragments in the series suggests that it is reasonably representative, unlike most early collections. The Bed 1 industry may be classified as typical Mousterian and that from Bed 2 as Mousterian of Acheulean tradition, with a high proportion of denticulate flakes in both industries. A number of close typological and technological similarities were seen in comparing the Mousterian of Acheulean tradition Bed 2 industry from Abri Brouillard and the Transvaal Earlier Fauresmith industry from Cave

of Hearths Bed 3, on a statistical basis. The detailed comparisons will be published elsewhere ("Cave of Hearths", monograph in preparation). Here we are concerned only with main features. The 'typical' *Mousterian industry of Abri Brouillard Bed 1* is similar to the Bed 2 series but has a lower proportion of bifaced hand-axes and cleavers, as shown in Table 3.

Table 3. FRENCH MOUSTERIAN

Site	Hand-axes and cleavers (per cent)	Flakes (per cent)	Total
Brouillard Bed 1	1	99	527
Brouillard Bed 2	27	73	481

The reason for the variable class proportions is unknown, but might be response to differing seasonal needs.

A similar position is seen in the Transvaal Wonderboom and Cave of Hearths Bed 3 series, now classified as *Transvaal Earlier Fauresmith (see preceding communication)*. The Wonderboom series consists of the same hand-axe, cleaver and flake classes found in Cave of Hearths Bed 3; but the flake classes are predominant, as in the 'typical' Mousterian of France (Table 4).

Table 4. TRANSVAAL FAURESMITH

Site	Hand-axes and cleavers (per cent)	Flakes (per cent)	Total
Wonderboom 76–79 in.	4	96	242
Wonderboom 39–42 in.	2	98	285
Wonderboom 6–18 in.	0·3	99·7	366
Cave of Hearths Bed 3	20	80	1,083

At Wonderboom we have the first evidence in Africa for the existence of a Fauresmith parallel to the French Typical Mousterian industry. Comparison of the Abri Brouillard, Cave of Hearths and Wonderboom industries shows not only general typo-technological resemblances but also similar variable production of the flake component in the Transvaal Fauresmith, French Typical Mousterian and Mousterian of Acheulean tradition cultures. While earlier comparisons were with the Mousterian in general, Wonderboom enables us to compare the Transvaal Fauresmith more specifically with the French *Mousterien typique*.

The Cave of Hearths Earlier Stone Age industries, best represented in Bed 3 at that site, were originally classified as Later Chelles–Acheul. The later Pleistocene fauna afterwards found with these Earlier Stone Age industries, among other factors, showed that they could not possibly be the same age as the Later Chelles–Acheul which, both on the Vaal River and in East Africa, is associated with a fauna of more archaic aspect. Subsequent statistical study showed that despite the close general resemblances of the Cave of Hearths Earlier Stone Age series and the Vaal Chelles–Acheul, they could be separated from the latter industries in statistical terms (see preceding communication). Statistical study of the Wonderboom series showed its close resemblances to the Cave of Hearths Bed 3 industry, in all except class proportions, forcing me to change my 1957 non-statistical classification of Wonderboom[13] as a Later Chelles–Acheul site and assign the entire series to the Transvaal Fauresmith culture. For these reasons I have come to suspect non-statistical classifications of Acheul industries found elsewhere, such as the 'Upper Acheul' industries from Mount Carmel[14] and Jabrud[15] in the Eastern Mediterranean area. Like the Wonderboom and Cave of Hearths Earlier Stone Age industries, these 'Acheul' series might prove to be considerably later than their non-statistical classification indicates. They may prove to be Eastern Mediterranean parallels of the French Mousterian of Acheulean tradition. At Jabrud Site 1, the 'Acheul' beds are intercalated with flake industries said by d'A. Waechter[16] to be "Acheulean without hand-axes", in my view, possibly the same as Typical Mousterian, though Bordes, who has studied the Jabrud series in detail, describes the Jabrudien as an eastern facies of the la Quina Mousterian[17].

So we are confronted with a curious dualism in Acheul derivative cultures spread from France, possibly to the eastern Mediterranean and appearing unexpectedly on the southern end of Africa at Wonderboom and Cave of Hearths. The racial type found with the French Mousterian is Neanderthal, while the Fauresmith horizon in Cave of Hearths Bed 3 yielded a jaw fragment tentatively classified as Neanderthal[18].

There can be little doubt that for the most part evolution in the South African Stone Age continues undisturbed from the very beginnings of the Stone Age until its end, with occasional migrations from neighbouring parts of Africa accounting for intrusive cultures such as the Smithfield and Sangoan, both the latter derived from the Congo. The unbroken nature of the culture sequence disproves claims for a 'Mousterian' invasion from the north, but does little to account for the Fauresmith–Mousterian parallels indicated in the present article. For the present, these widely separated racial and cultural resemblances, occurring in radically different ecological settings, must be regarded as an enigma, unless they are explained by derivation from a single source followed by evolution in isolation during an immensely long period of time. The preservation of genetic and cultural similarities could have been due to an unexplained biological and psychological conservatism.

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LETTERS TO THE EDITORS

OCEANOGRAPHY

Measurements of the Pacific Equatorial Countercurrent

As part of *Doldrums*, the third of three International Geophysical Year oceanographical expeditions of the Scripps Institution of Oceanography, direct current measurements were made in the centre of the equatorial countercurrent, 7° 52′ N., 107° 30′ W. The techniques were similar to those used three months previously, when measurements were made of the Cromwell current at the equator, 140° W.[1]. In the top 300 m. observations were made by suspending a propeller-type current meter (a modified Roberts meter) from a drifting ship and measuring the apparent velocity at different depths from the flow of water past the meter while at the same time observing by radar the drift of the ship from a fixed reference point—a taut wire buoy anchored in 2,200 fathoms. Below 300 m. measurements were made by following the drift of Swallow current floats[2].

Calculations of the geostrophic current as well as other considerations have led to a picture of the countercurrent as a shallow current the maximum velocity of which is to be found somewhat below the surface, but the flow of which is confined almost entirely to the region in and above the sharp tropical thermocline. Direct current measurements made on *Doldrums* modify this picture. The highest velocities in the countercurrent are found above the thermocline, and the peak velocity is found beneath the surface but in the mixed layer. However, the countercurrent does not vanish beneath the thermocline but continues to flow east at speeds of 15–20 cm./sec. Fig. 1 is a plot of the east–west current component as measured on *Doldrums*. The current profile above 200 m. is a composite of 12 Roberts meter stations taken over a two-week period; below 200 m. the curve is drawn to the six Swallow current float measurements summarized in Table 1. The depth of the thermocline as measured by the bathythermograph is also shown.

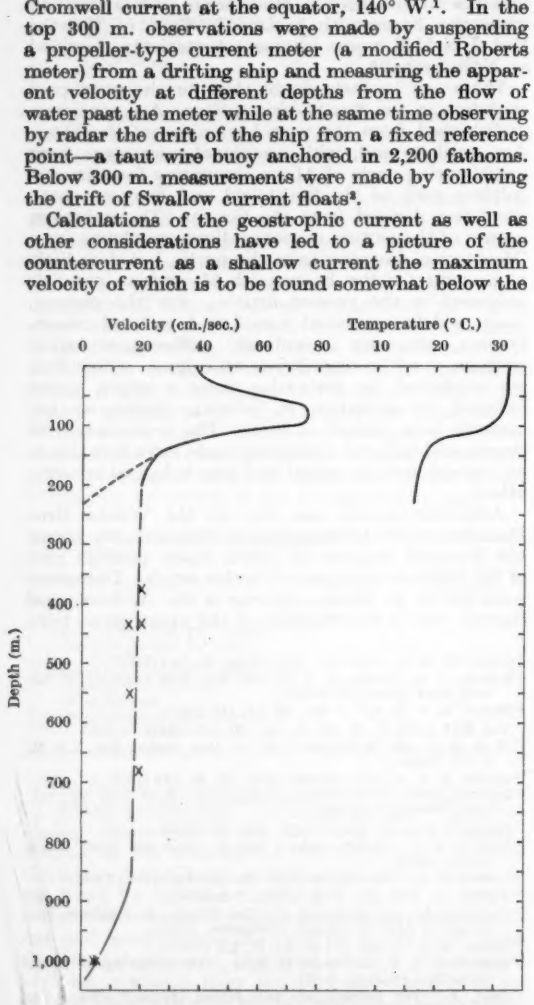

Fig. 1. Current and temperature profile in Pacific equatorial countercurrent, 7° 52′ N., 107° 30′ W. Transport calculation above and below the thermocline were made relative to the dashed line

Table 1

Date	Hours tracked	Depth (m.)	Velocity (cm./sec.) – direction (toward)
August 12	7·2	370	20 — 080°
15	12·5	680	20 — 100°
16	16·0	590	16 — 085°
17	14·2	1,000	5 — 085°
18	7·3	1,000	5 — 135°
26	14·9	430	16½ — 115°

The results summarized in Fig. 1 indicate that the countercurrent transports more water below the thermocline than above it. The width of the countercurrent during this period was 250–300 km. Making some allowance for a decrease in the current near its edges a rough estimate of the transport of the countercurrent based on this one profile is 20×10^6 m.³/sec. for the region above the thermocline and 30×10^6 m.³/sec. for that below the thermocline. The estimated transport above the thermocline agrees with that given by Sverdrup[3] for the countercurrent ($20–25 \times 10^6$ m.³/sec.).

The problem of water balance and mass transport in the equatorial Pacific must be re-examined and at least one detailed north–south section of direct current measurement stations is required. The measurements of the Cromwell current in May, 1958, showed[1] an eastward transport of 30×10^6 m.³/sec. The present observations imply that there is an additional transport of 30×10^6 m.³/sec. in the countercurrent below the thermocline. These additions more than triple the total eastward transport in the equatorial Pacific as given by Sverdrup[3].

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GEOPHYSICS

Geomagnetic Micropulsations

A DETAILED analysis of geomagnetic micropulsations has been carried out on records obtained at Albert Head between November 29, 1956, and February 16, 1957. Albert Head (approximately 48° 23′ N., 123° 29′ W.) is situated by the sea near Victoria, Vancouver Island, British Columbia. The records were obtained from three mutually perpendicular air-core induction coils, each 20 ft. in diameter, mounted in a rigid wooden octahedron[1]. The records were analysed by visual inspection: more than 300 fluctuations were identified with periods ranging from 15 to 400 sec. Their amplitudes were read and reduced by simple computation to components X (north), Y (east) and Z (vertically downwards). Plots were made of these three components against the period T of the oscillations, but yielded little information. There was a tremendous scatter in the points, and it was impossible to draw any mean curve through the data. The only conclusion that could be drawn was that, in general, the amplitude appeared to increase with the period.

The same data were then taken and the amplitude of every fluctuation divided by the K_p index at the time the observation was made. Plots were drawn of X/K_p, Y/K_p and Z/K_p against T. There was a very considerable reduction in the scatter, which was further reduced if local K indices (instead of K_p) were used. A least-squares analysis gave extremely interesting results. The graphs of both X/K_p (Fig. 1) and Y/K_p (Fig. 2) consist of parts of two straight lines—the change of slope occurring at a period of about 2 min. An investigation is now being made to see whether these may represent two different kinds of magnetohydrodynamic waves—poloidal and torsional oscillations. The graph of Z/K_p (Fig. 3) is almost linear. It would be interesting if similar calculations

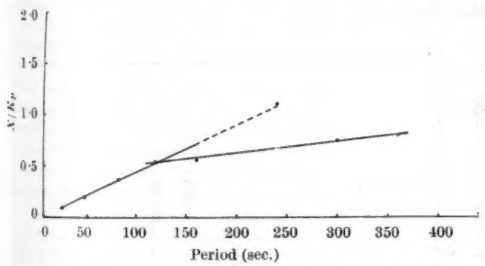

Fig. 1. X/K_p plotted against period (Albert Head, November 1956–February 1957)

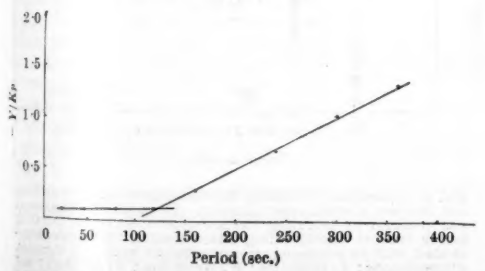

Fig. 2. $-Y/K_p$ plotted against period (Albert Head, November 1956–February 1957)

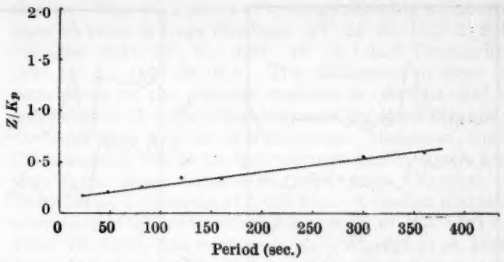

Fig. 3. Z/K_p plotted against period (Albert Head, November 1956–February 1957)

were made at other stations and at different periods of the year. The above method of analysing the data may not be the best, but was continued since the early results were encouraging. The smallest K_p value was 1·0. A detailed account of this study is being prepared.

This work is supported by the Defence Research Board of Canada and was carried out last summer at the Pacific Naval Laboratory, Esquimalt, British Columbia.

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Storm-Time Increase of Cosmic-Ray Intensity

DURING the period of the International Geophysical Year (July 1957–February 1958) there were several occasions in which the intensity of cosmic rays increased by a few per cent. Two typical events, which occurred on September 13, 1957, and February 11, 1958, respectively, will be described here.

Since the change in intensity is complicated by the diurnal variation, the world-wide type of decrease and so on, the increases observed at any particular position may be depressed or exaggerated. In order to study the characteristics of an increase more clearly, Fig. 1 was prepared. The four curves represent the variation in intensity averaged for two or three stations distributed symmetrically in geographical longitude (Table 1), so that any diurnal variations may be approximately smoothed out[1]. From Fig. 1 it is seen that the cosmic-ray intensities increased

Table 1. STATIONS USED IN COMPILATION OF DATA FOR FIG. 1

Symbol	Component	Station	Altitude (m.)	Geomagnetic latitude	Geographical longitude
I_1	Neutron	Norikura	2,770	25·6° N.	137·6° E.
	,,	Zugspitze	2,960	48·2° N.	11·0° E.
	,,	Climax	3,400	48·2° N.	106·2° W.
I_2	,,	Yakutsk	S.L.	51·0° N.	129·6° E.
	,,	Göttingen	273	52·3° N.	9·9° E.
	,,	Chicago	S.L.	52·6° N.	87·7° W.
I_3	,,	Mawson	S.L.	73·1° S.	62·9° E.
	,,	Resolute	S.L.	82·9° N.	94·9° W.
I_4	Meson (ion chamber)	Yakutsk	S.L.	51·0° N.	129·6° E.
	,,	Moscow	S.L.	50·8° N.	37·3° E.
	,,	Fredericksburg	S.L.	50·0° N.	76·7° W.
H	Geomagnetic horizontal				
K_p	K_p index	Kakioka	S.L.	26·0° N.	140·2° E.

S.L., sea-level

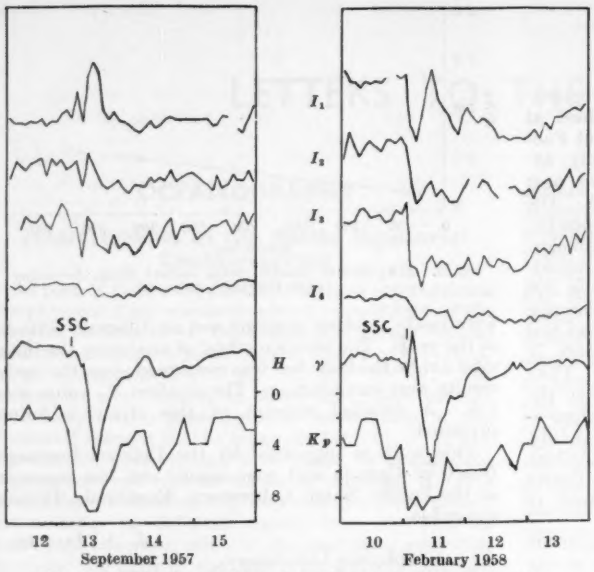

Fig. 1. World-wide variations of cosmic-ray intensities obtained by averaging data from the station in Table 1, and the change of magnetic activity

abruptly by about 2 or 3 per cent on a world-wide scale regardless of diurnal variation. (This does not exclude the possibility of the longitude variation of increment.) The times of maximum intensities were 9 hr. ± 1 hr. on September 13 and 11 hr. ± 1 hr. on February 11, respectively.

The variations of horizontal magnetic force observed at Kakioka as well as the international magnetic activity index (K_p), are also plotted in Fig. 1. It was found that the increase in intensity of the cosmic rays coincided with the severest phase of magnetic storms. The magnetic storm in February was one of the severest in recent years, and that in September was almost as severe. Many magnetic observatories reported a K_p index of 9 for the interval containing the cosmic-ray increase in each storm. It is of interest that, during these storms, aurorae were seen in such low latitudes as those of Japan[2].

Large solar flares, which appear to be the cause of these storms, occurred at 02h. 45m. on September 11, and at 21h. 08m. on February 9, respectively; none was seen before or during the actual time of the increases. These increases, therefore, seemed to differ from the so-called extraordinary increases of cosmic rays, a fact that is confirmed by the mode of variation in latitude shown in Fig. 2. Usually, the solar cosmic rays predominate in higher latitudes, but the increases described here were most pronounced in lower latitudes.

The variation with latitude of the increment in Fig. 2 may be outlined as follows: the increment increases slightly with the latitude from the equator to about 50° N.; it then decreases steeply, and reaches a constant level which is rather difficult to evaluate, however, because of the process of normalization.

In order to illustrate the dependence upon energy of the increments, a comparison in variational amounts of the increase and decrease was made as shown in Fig. 3. The increment seems to be proportional to the amount of decrease, which is itself a function of altitude and component. Since the stations chosen lie in the region of latitude lower than 50° N., it may be said that the dependence upon energy of the cosmic-ray increase is nearly the same as that of the decrease.

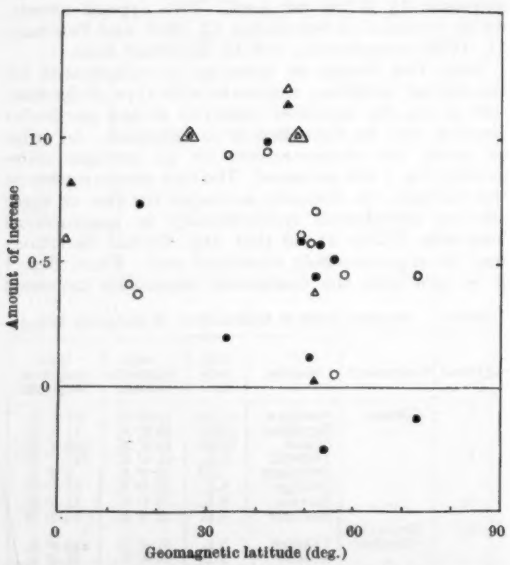

Fig. 2. Variation with latitude of the cosmic-ray increment. Each increment is calculated as the difference in intensity between the time of the increase (6 hr. around each maximum) and 6 hr. before and after the increase. An adjustment has been made to eliminate dependence on longitude. Because the increases were less significant, results for American regions are omitted. Circles, sea-level stations; triangles, mountain stations; ○ and △, September; ● and ▲, February. Double triangles, stations for I_1 in Fig. 1 which were used as normalization points

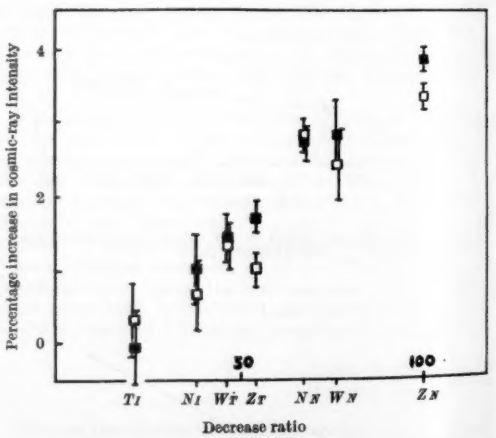

Fig. 3. Quantitative relation between the world-wide decrease and increase of cosmic-ray intensity. The scale for the abscissa was obtained by averaging the amounts of decreases occurring during 1957 at corresponding stations using the apparatus indicated, with an estimated error of approximately 3 on the scale. Abbreviations: Z, Zugspitze; W, Weissenau; N, Norikura; and T, Tokyo. Subscripts: N, neutron; T, meson monitor; and I, ion chamber. The errors in ordinate are the statistical values. The zero line of the ordinate is subject to slight adjustment in the calculation of intensity-level

We wish to thank the staffs of the cosmic-ray observatories throughout the world for the results used and Dr. Y. Miyazaki for allowing us to use the data compiled in the World Data Centre of Cosmic Rays in Japan.

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Occurrence of Giant Travelling Ionospheric Disturbances at Night

A RECENT publication[1] from this laboratory has discussed the existence of large travelling ionospheric disturbances which during winter daylight hours travel from south to north over the east coast of Australia. This type of disturbance first described by Munro and Heisler[2] has been tracked from Hobart to Townsville, a distance of 3,000 km. with no apparent change in amplitude. Moreover, the frontal extent of the phenomenon is at least 1,000 km. and may be greater. Munro[3] found evidence in the northern hemisphere ionosonde records of similar disturbances travelling south during the winter months. This has been confirmed by Wells[4] and verified at Stanford University in a recent report[5] which shows how back-scatter techniques have been used to find many examples of giant travelling ionospheric disturbances, some of which have been shown to extend at least from the east to the west coasts of America and to travel distances of 4,000 km.

It was previously thought that this phenomenon was confined to daylight hours, but recently careful investigation of night ionosonde records has revealed anomalies which are obviously a counterpart to the disturbances discussed above.

This phenomenon is characterized by a rapid fall in virtual height of the *F*-layer accompanied by a reduction in critical frequency; a cusp then appears at the top of the *F*-layer in the form typical of a daylight record with *F*1 stratification. This stratification then disappears and as a consequence leaves a high *F* region trace. The layer then slowly falls to its original height. Part of the sequence at a particular ionospheric station is shown in Fig. 1.

These disturbances are infrequent and seldom occur more than once a night or on more than two or three nights a week, and consequently identification on ionosonde records from a number of stations is conclusive. Fig. 1 is a series of tracings showing a disturbance on records from Brisbane (27° 28′ S., 153° 2′ E.), Camden (34° 03′ S., 150° 40′ E.) and Townsville (19° 10′ S., 146° 58′ E.). The difference in time of occurrence at the various stations is obvious and is consistent with a disturbance travelling approximately due east with a speed of 8 km./min. Moreover, since these stations lie in an approximate north–south line the fronts must extend at least from Camden to Townsville, a distance of 1,800 km. A similar disturbance occurring on the Camden record at 2220 hr. on June 26, 1957, has been positively identified at Brisbane and Townsville and was travelling 46° east of north with a speed of 16 km./min. Watheroo (30° 18′ S., 115° 56·6′ E.) record for the same night showed a similar disturbance but with a difference in time which would suggest that the disturbance front was curved with a direction of travel north-west in Western Australia and north-east in Eastern States. Unfortunately, there are no ionospheric stations in the east – west line between Camden and Watheroo, a distance of 3,300 km., to determine this positively.

There are as yet insufficient results to interpret the seasonal variation of occurrence, although examples have been found during March, June and July. Research into the phenomenon is continuing and it is hoped that the discovery of such disturbances in the much simpler ionospheric conditions existing at night may help materially in determining the mechanics of the phenomenon.

Grateful acknowledgment is made to the Ionospheric Prediction Service of the Department of Interior and the Geology and Geophysics Division of the Bureau of Mineral Resources for their co-operation in providing ionosonde records for this research. This work is part of the investigations of the Sydney Laboratory of the Radio Research Board in the

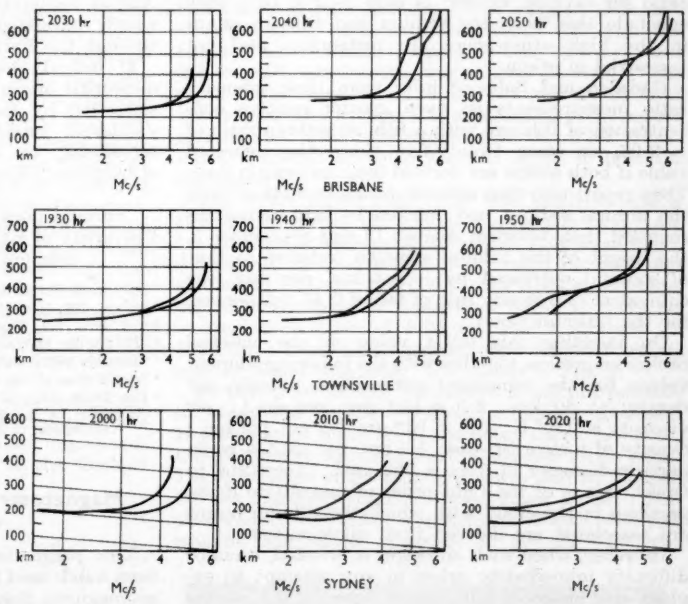

Fig. 1. Tracings of ionosonde records from Brisbane, Townsville and Sydney for July 5, 1957, showing giant travelling ionospheric disturbance. Speed 8 km./min. in a direction 85° E. of N.

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Origin of Upper-Atmosphere Lithium Atoms responsible for the New Twilight Airglow at 6708 A.

A new emission line near 6708 A. has been reported recently by Delannoy and Weill[1] to be present on twilight spectrograms obtained in Adélie Land, Antarctica, during October 1957. Gadsden and Salmon[2] also report the appearance of the same line in twilight spectra photographed at Hallett Station, Antarctica, during August, 1958, and at Invercargill, New Zealand, on September 5, 1958. In both instances, the authors attribute the new line to resonance radiation from the 2^2S—2^2P transition in the neutral lithium atom at 6707·8 A.

In a further communication, Barbier, Delannoy and Weill[3] estimate the ratio of the number of neutral atoms of lithium to those of sodium at the level of twilight emission, taking into account the very different energy of the exciting solar radiation at 5893 A., and 6708 A. respectively. From an observed intensity ratio, $I_{6708}/I_{5890+5896}$, equal to 0·1 : 1, they compute an abundance ratio of N_{Li}/N_{Na} of $\sim 0{\cdot}006$, about three times greater than that found in stony meteorites[4]. Since the lithium/sodium concentration ratio for oceanic waters[5] is only $\sim 2 \times 10^{-5}$, they conclude that both the sodium and lithium atoms in the high atmosphere are meteoritic, and not terrestrial in origin.

Gadsden and Salmon[2] infer from their intensity ratio measurements an even greater relative concentration of lithium, with a lithium/sodium ratio of $\sim 0{\cdot}05$, or some twenty-five times the expected value if both atoms are derived from meteoritic dust. They report also that altitude measurements of both the normal sodium and lithium twilight radiations revealed that, between August 13 and September 5, the height of the lithium emission (relative to that of sodium) decreased by $\sim 0{\cdot}4$ km. per day, the equivalent of a steady rate of fall of 0·46 cm. per sec. for the 'lithium cloud'.

On inserting this latter value in the classical Stokes's equation, together with the following adopted values for the remaining parameters, namely, air density at 80 km., $2{\cdot}5 \times 10^{-8}$ gm. per cm.^{3}; air viscosity at 190° K., $1{\cdot}2 \times 10^{-4}$ gm. per cm. per sec.; density of meteoritic dust, 3·5 gm. per cm.^{3}, a mean particle diameter of $5{\cdot}4\mu$ is obtained. According to Öpik[6], this is of the right order of magnitude if the particles in the cloud with which the lithium atoms are associated are derived from micro-meteors.

However, when such an origin is invoked, a major difficulty immediately arises in any attempt to explain the observed differential rate of fall of the lithium emission, since this would not be expected if both lithium and sodium atoms were associated with a falling cloud of meteoritic material.

The above argument, when taken in conjunction with the excess values of the lithium/sodium abundance ratio observed in 1957 and 1958, makes any hypothesis of a meteoritic origin for either element suspect. On the other hand, it lends credence to the recently published statement by the American Committee for the International Geophysical Year[7] that the presence of lithium in the upper atmosphere could be related, as was the recent artificial aurora[8], to nuclear (lithium bomb) explosions detonated at high altitude over the central Pacific Ocean during the period of the International Geophysical Year programme.

If the latter explanation is correct it is of interest to compute a revised value for the mean particle diameter in the descending cloud on the assumption that the radiating lithium atoms are trapped within a cloud of lithium oxide smoke of density 2·1 gm. per cm.^{3}. Taking values for the remaining Stokes's parameters as before, the average particle size is now $\sim 7{\cdot}0\mu$; and if the ejection of the lithium atoms occurred initially at a height of ~ 160 km. the twilight phenomena might be expected to be present for about 90 days after the nuclear explosion. During this interval the 'lithium cloud' would have fallen from the upper to the lower limit of resonance emission.

From the evidence of the August, 1958, observations it appears that there was a five-day lag between the time of the nuclear detonation on August 1 and the first appearance of twilight lithium radiation. Thus the initial rate of fall must have been considerably higher than the steady descent of 0·4 km. per day observed afterwards, a probable value being ~ 10 km. per day if the upper limit of twilight emission is taken to be 110 km.

Taking all the above facts into consideration, it appears highly probable that the lithium airglow emission observed in October 1957, and again in August–September 1958, was man-made, and thus wholly unrelated to the passage of meteoritic dust through the Earth's upper atmosphere.

If indeed this is correct, the hypothesis of a meteoritic origin for both lithium and sodium atoms suggested by Barbier, Delannoy and Weill[3] is invalidated, leaving the important question of the terrestrial, or extra-terrestrial, origin of upper-atmosphere sodium still unanswered.

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Magnetostriction and Palæomagnetism of Igneous Rocks

The magnetization of dated igneous rocks has been much used for the study of the directions of the geomagnetic field in remote geological periods. This method is based on the supposition that igneous rocks become magnetized parallel to the field in which they cool. Its validity has been questioned

on the grounds that the stress-histories of rocks may have a substantial influence on the directions of their remanent magnetic moments[1–3]. In particular it has been suggested that igneous rocks which cool under stress become magnetized in the direction of the prevailing field, but that when the stresses are released, substantial changes in direction may occur. Sills cooling under load and lava flows subject to cooling stresses present situations of the type envisaged: when specimens of such rocks reach the laboratory their original stresses have been relieved by erosion of overlying rock and the removal of the specimens from the ground.

Presumptive evidence for such magnetostrictive effects has been given by Graham, Buddington and Balsley[3], who subjected a number of metamorphic rocks to linear compressions of 250 kgm./cm.^{2} without heating and found reversible deflexions of up to 30° in the directions of magnetization. (It may be noted that no authors have used metamorphic rocks to draw conclusions about the directions of the Earth's magnetic field.) Stacey has pointed out[4] that, while the pronounced effect of isothermally applied axial compression is theoretically reasonable, it does not follow that thermo-remanent magnetization acquired under stress will show irreversible deflexions when the stress is removed. Field evidence[5] suggests the absence of large magnetostrictive effects.

A crucial laboratory experiment consists of subjecting igneous rock specimens to axial stress while they cool from high temperatures in a magnetic field, and then comparing the directions of the resulting magnetic moments after subsequent release of stress with that of the field. Accordingly, we have built a special non-magnetic press and heating system and made experiments on a number of igneous rocks from eastern Australia for which palæomagnetic data have been reported. Twenty cylindrical specimens covering a wide range of rock types, ages and geological environments, namely, Quaternary basalts, Mesozoic dolerite sills, Permian basalts, Devonian basalt and rhyolite flows, and Silurian porphyry of andesitic composition were placed in the press with their axes in the magnetic meridian. They were heated to 650° C. in a nitrogen atmosphere, held at that temperature for 15 min. and then allowed to cool over a period of several hours under an axial load of 500 kgm./cm.^{2}. The directions of magnetization of all the specimens were measured after their removal from the press. Errors of measurement and of alignment of specimens in the press were estimated by means of a duplicate set of specimens, which were given the same heat treatment, but without stress. The experiments were carried out in a non-magnetic hut where the geomagnetic dip I is 66° ± 1°. The results are summarized in Table 1, where $\bar{\theta}$ is the mean of the angles between the magnetic moments of the specimens and their axes, and δ is the standard deviation of the individual variations from the mean. Within the limits of the experiment, all the rocks, both stressed and unstressed, acquired moments in the direction of the field in which they cooled.

Table 1

	No. of specimens	I	$\bar{\theta}$	δ
Cooled under no load	20	66°	65·2°	2·5°
Cooled under 500 kgm./cm.^{2}	20	66°	65·4°	2·6°

This excellent agreement between the dip and the directions of artificial thermoremanent magnetization of the stressed and unstressed rocks indicates that large systematic errors due to magnetostriction are most improbable in igneous rocks of types normally used for palæomagnetic work.

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Dec. 9.

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PHYSICS

'Whistler Mode' Echoes remote from the Conjugate Point

Echoes of very low frequency radio signals from station *NDT* on 17·44 kc./s. in Tokyo (25° N. geomagnetic latitude) with delays of about 0·2 sec. have been detected at Hobart, Tasmania (51° S. geomagnetic latitude). The Eckersley–Storey theory of 'whistler' propagation predicts that 'whistler mode' signals from Tokyo would return to the Earth's surface at a point (the geomagnetic conjugate point to Tokyo) near Darwin, Northern Territory, some 3,500 km. from Hobart.

The signals used were $\frac{1}{8}$-sec. pulses sent every second for a 4-min. period. These transmissions were specially arranged by the Australian National Committee of the International Geophysical Year for a conjugate point experiment. The receiving equipment consisted of a single-turn, crossed-loop system, 70 ft. high, fed through a goniometer into a made-up receiver having four tuned radio-frequency stages and two tuned intermediate-frequency stages. The enclosed area of each loop was about 900 m.^{2}, the receiver intermediate frequency was 750 c./s. and the overall band-width was about 15 c./s. The signals were recorded on tape. The null direction of the crossed-loop system was adjusted so as to reduce considerably the direct signal since the *NDT* transmitter radiated a strong residual signal in between the pulses.

The direct signal from *NDT* was received with a strength of about 150 μV./m. during the day. All measurements were made at about 1250 local time. A series of distinct echoes were heard on only one of the five periods observed (1251½ E.A.S.T., September 30). On analysis these were found to have an average time delay of 0·21 sec. and a strength of 3 μV./m. Four direct pulses, each followed by an echo of about this delay, are shown in Fig. 1.

As only a few echoes were heard it was not possible to locate the source by direction-finding methods. It seems most likely from the delay times, however, that the echoes travelled via the 'whistler mode' from Tokyo to somewhere around Darwin and to Hobart via the Earth – ionosphere wave-guide mode. The observed 0·2-sec. delay is in agreement with observed whistler dispersions (from 30 to 50) for this geo-

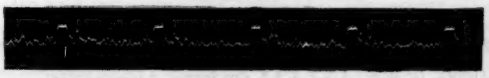

Fig. 1

magnetic latitude[1] and with a similar whistler mode echo experiment[2], using the station *NPM*, which is also on about this same geomagnetic latitude. The actual time spent in the whistler mode is found by adding the travel time for the direct pulse from Tokyo to Darwin (0·02 sec.). This time is then 0·23 sec.

Use can be made of these results to estimate the minimum electron density on the line of force originating from the transmitter. Whistler mode echoes of very low-frequency stations have an advantage over natural lightning flash whistlers in that the position of the transmitter is readily and accurately known. As borne out by this experiment, the assumption that short whistlers originate near one's conjugate point could lead to an error of more than thirty degrees of latitude.

The whistler mode delay time for a signal of frequency f travelling along a line of force in a medium of plasma frequency f_p and gyro frequency f_H is given by Storey's[3] equation (15) provided $f_H \gg f$ and $f_p^2 \gg f f_H$:

$$t = \frac{1}{2c}\int f_p\,(f f_H)^{-1/2}\,ds$$

If we assume a dipole field and a constant electron density along the line of force (neglecting, for the moment, the effect of the lower ionosphere), we can get the approximate expression:

$$t \approx \frac{R_0}{c} f_{p_0}\,(f f_{H_0})^{-1/2}\int_0^{x_g} (1-x^2)^{3/2}\,(1\ 3x^2)^{1/4}\,dx$$

$$\approx \frac{R_0}{c} f_{p_0}\,(f f_{H_0})^{-1/2}\,x_g(1-\tfrac{1}{4}x_g^2) + \text{terms in } x_g^5 \qquad (1)$$

where R is the distance from the Earth's centre (in units of the Earth's radius) and x is the sine of the geomagnetic latitude angle. The subscripts 0 and g refer to values in the geomagnetic equatorial plane and at the Earth's surface respectively. The maximum value of x is $x_g = \sin 25° = 0{\cdot}4$, so to within an accuracy of a few per cent we may neglect terms in x^4.

To this must be added a correction to take account of retardation through the lower ionosphere. Considering only the F region and assuming a parabolic layer of semi-thickness y_m, critical frequency f_{pc} and magnetic dip angle φ and assuming all other quantities to be constant within the integration limits, we find the correction to be applied is:

$$\Delta t = \tfrac{1}{4}\pi f_{pc}\,(f f_H)^{-1/2} y_m\ \mathrm{cosec}\ \varphi \qquad (2)$$

We can apply equations (1) and (2) to find f_{p_0} at R_0. On substitution of $x_g = \sin 25°$ and $t + \Delta t = 0{\cdot}23$ sec. we find $\Delta t = 0{\cdot}04$ sec. $R_0 = 1{\cdot}22$ radii and $f_{p_0} = 1{\cdot}75$ Mc./s. This suggests an electron density of about 20,000 cm.$^{-3}$ at a height of about 1,400 km.

We wish to thank Dr. G. R. Ellis, Upper Atmosphere Section, Commonwealth Scientific and Industrial Research Organization, for his useful suggestions.

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Multiple Geiger Counter Telescope Measurements of the Directions of Air Shower Particles

A multiple Geiger counter telescope was described recently by Shen and Singer[1], for which it was claimed that it responded preferentially to air showers the axis of which were parallel to the direction of the telescopes. Such an arrangement was tested by Layson, Malos and Millar[2] in a scintillator array with which total number of particles, situation of core and direction of shower axis were determined. The result of the latter investigation, namely, that the multiple Geiger counter telescope does not select in larger proportion air showers of preferred orientation, is supported by an unpublished experiment made by me in 1948 while at the School of Physics, University of Melbourne.

The arrangement used consisted of two Geiger counter telescopes, separated by 1 m., which could be tilted independently around an east–west axis. Each telescope consisted of two counters, 20 cm. long and of 3 cm. diameter, separated by 14 cm. A third counter could be introduced either in line or just outside the space joining the two outermost counters. The resolving time of 8 μsec. gives a rate of accidental counts of 10^{-3} per hr. for both the fourfold and sixfold coincidences, the main contribution being the accidental coincidences between the two telescopes.

The results of measurements made in a tent at an altitude of 1,750 m. are given in Table 1.

Table 1. Shower-rate in Counts per hr. at Different Zenith Angles

Zenith angle		Counters in each telescope		
Telescope 1	Telescope 2	2 counters	3 counters in line	3 counters centre out of line
0°	0°	1·96±0·29*	1·56±0·27	1·19±0·24
30° N.	30° N.	1·50±0·27	1·41±0·24	0·98±0·22
60° N.	60° N.	1·23±0·22	0·66±0·17	
90° N.	90° N.	1·25±0·23	0·77±0·16	0·94±0·22
30° N.	30° S.		1·04±0·22	
60° N.	60° S.		0·67±0·17	

* The errors given are standard errors.

While the statistical accuracy is not sufficient to draw detailed conclusions, it is sufficient to show that such an arrangement of Geiger counters as was used does not respond selectively to showers incident within the opening angle of ± 12° of the telescopes. However, taking the three measurements at 60° and 90°, which give a mean of 0·70 ± 0·10, as general background due to showers arriving in all directions, we find that 0·87 ± 0·29, or about half the counts measured in the vertical position, are due to showers arriving from the zenith region. The excess of 0·71 ± 0·26 above background at 30° zenith angle gives an effective acceptance angle of ± 20–30° for that part of the rate which exceeds the background. The broadening can be explained both by the divergence of particle tracks in showers and by the fact that one particle only may frequently pass through two counters. The second effect is shown in the excess of the out-of-line measurements, the first in the excess of 0·37 ± 0·24 above background of the measurement at 30° N. 30° S., that is, with a divergence of the two telescopes of 60°.

As soon as it was evident that multiple telescopes were not sufficiently efficient in selecting

showers incident in preferred directions the experiment was discontinued.

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Permeability of Porous Media

Over the past decade much significance has been given to distribution of pore size characteristics in computing both saturated and unsaturated permeability of porous materials. Oil industry investigators[1] and soil scientists have adopted this approach to permeability computation with considerable success.

Childs and Collis-George[2] proposed a theory wherein flow is determined by the pore radii and by the probability of continuity of pores of different radii in adjacent planes. Marshall[3] greatly facilitated computation by using arbitrary equal volume components of the porosity.

Both these approaches show defects. The ratio of the observed and calculated permeability at saturation was used by Childs and Collis-George as a 'matching factor' to compute values for unsaturated permeability. If instead of the 'matching factor' (M), pore radii (not $1/h$) and the Poiseuille coefficient 1/8 are used, the computation yields the same result as the method of Marshall. Using the 1–½ mm. sand data of Childs and Collis-George, both the above methods give a calculated permeability at saturation of 76×10^{-8} cm.^{2} against the experimentally determined value of 144×10^{-8} cm.^{2}. The form of the curve calculated by these methods for permeability against water-filled pore space does not fit the experimental findings. In the following paragraphs an alternative theory is proposed.

In a porous medium of porosity ε, the effective area available for flow may be defined with reference to the volume distribution of pore space thus:

$$\frac{\text{effective pore area}}{\text{pore volume}} = (n^2\pi r^2/n^3\pi r^3) \cdot (k_1/k_2)$$

where there are n^3 pores or radius r in unit volume of the medium; k_1 and k_2 are characteristics of the shape of pore and for nearly spherical pores may be neglected in the subsequent derivation. From this relationship it can be shown that the effective pore area available for flow per unit area of section is $\varepsilon^{2/3}$. If there are m pore classes each occupying a volume component ε/m of the total porosity, then the effective flow area presented by each pore class is $\varepsilon^{2/3}/m$. However, flow is determined by the pore interaction or continuity between adjacent sections, so that permeability is determined by the sum of:

$$a_1a_1r_1^2 + a_1a_2r_2^2 \ldots\ldots a_1a_mr_m^2$$
$$\vdots$$
$$a_ma_1r_m^2 + a_ma_2r_m^2 \ldots\ldots a_ma_mr_m^2$$

where a_1, a_2, etc., are the pore areas devoted to pores of radius r_1, r_2, etc., in unit area of section.

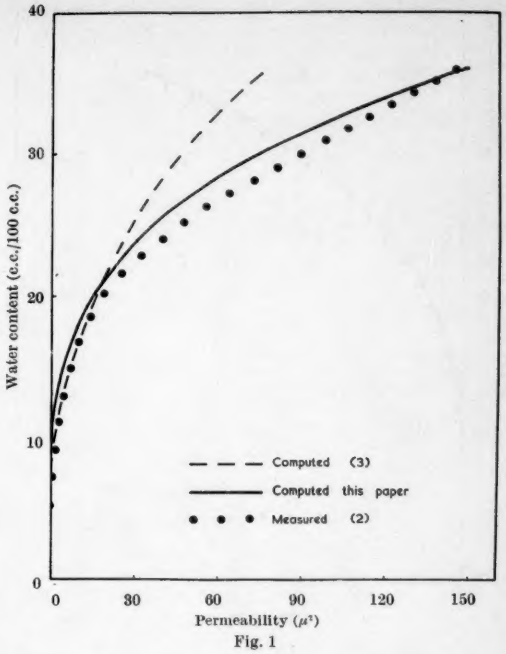

Fig. 1

Since there are m equal volume components of the porosity:

$$a_1a_1 = a_1a_2 = \ldots a_ma_m \text{ and}$$
$$a_1a_1 = \varepsilon^{2/3}/m \cdot \varepsilon^{2/3}/m = \varepsilon^{4/3}/m^2;$$

when the Poiseuille coefficient is included the intrinsic permeability (K) is then given by:

$$K = \varepsilon^{4/3}m^{-2}[r_1^2 + 3r_2^2 \ldots\ldots (2m-1)\,r_m^2]/8 \quad (1)$$

The units of K are cm.^{2} but for convenience in Figs. 1 and 2, K is expressed as μ^2.

For calculation of unsaturated permeability the value of ε adopted is that of the water-filled pore space and m remains constant. The r^2 series is commenced at the largest water-filled pore class. The basis for the variation of ε is due to changes in the water velocity which are not accounted for in the r^2 term of (1).

Figs. 1 and 2 enable a comparison to be made between the various methods for calculating permeability and the experimental results obtained by Childs and Collis-George for their 1 – ½ and ½ – ¼ mm. sands respectively. It can be seen from these figures that over a wide range of water content the curves calculated by the method herein proposed lie close to the experimental curves of permeability plotted against water content. The computed curves obtained either by the method of Childs and Collis-George (excluding M but including r and Poiseuille's 1/8) or by the method of Marshall are included for comparison; these latter curves clearly indicate that at high water contents the computed permeabilities are lower than those found experimentally.

Carman[4] has obtained the pore radius – volume curve for a Linde silica plug ($\varepsilon = 0{\cdot}506$); using these data and assuming an immobile monolayer the permeability of the plug has been calculated to be $2{\cdot}6 \times 10^{-15}$ cm.^{2}. This compares with the measured permeability[5] to CF_2Cl_2 at $-33{\cdot}1°$ C. of $3{\cdot}1 \times 10^{-15}$ cm.^{2}. It is interesting to note that the proposed

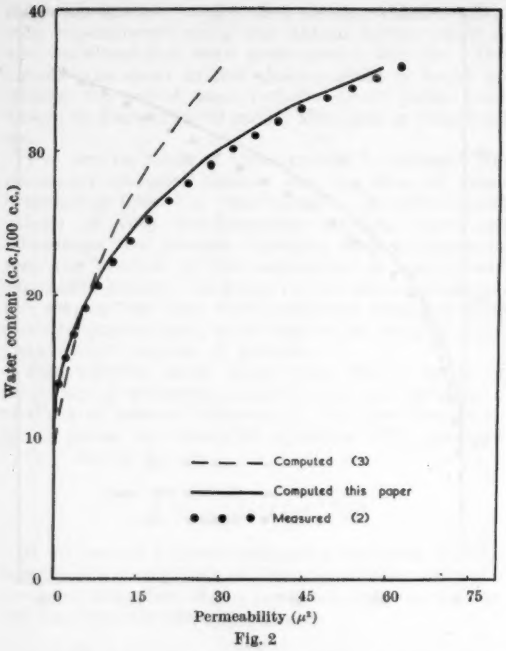

Fig. 2

equation for permeability calculation applies over a wide range of permeability, since the permeability of the Linde silica plug is almost 10^{-9} less than that for the $1 - \frac{1}{2}$ mm. sand.

A more extensive report of this work is being prepared for publication.

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CHEMISTRY

Effect of Thermal Neutron Irradiation on Oxide Catalysts for the Decomposition of Nitrous Oxide

Effects of radiation on catalysis have been investigated in various ways[1], including those of thermal neutron irradiation[2]. As thermal neutrons are of low energy, usually only a high flux density or a long exposure induces any change in catalytic activities. In this communication, however, we can report distinct effects on the catalytic activities of nickel oxide, aluminium oxide and stannic oxide used for the decomposition of nitrous oxide. The conditions were as follows: flux density, $10^{11} n/cm.^2 sec.$; exposure time, 3 hr. With the aid of the (n, α) reaction of lithium-6 or boron-10 atoms, we may expect an intimate relationship between the catalytic activity and the lattice defects in the semi-conductor catalysts.

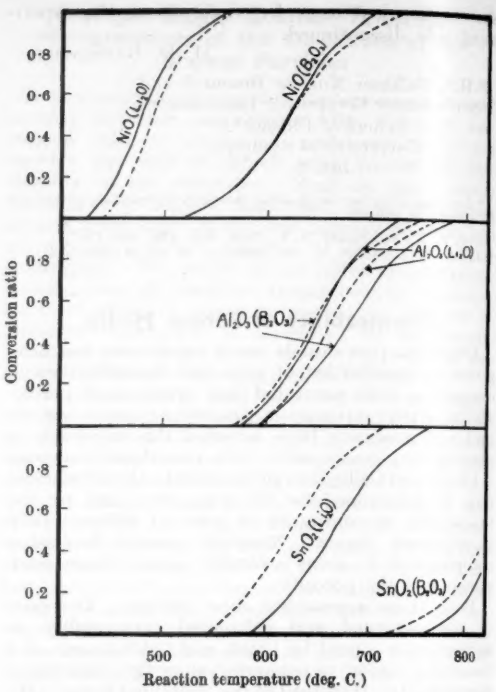

Fig. 1. Conversion ratio of nitrous oxide as a function of reaction temperature. The curves show the effect of thermal neutron irradiation on oxide catalysts. ——, Before irradiation; – – –, after irradiation

Separate samples of matrix powders of basic nickel carbonate, aluminium hydroxide and stannic hydroxide were dipped into aqueous solutions of lithium carbonate and boric acid, dried and fired at 750° C. for 2·5 hr. Lithium or boron atoms probably become distributed uniformly in matrices as oxides, the mixing ratio of atoms being 10 per cent, except for 1 per cent for lithium oxide in nickel oxide. The catalysts were irradiated in the *JRR*-1 nuclear reactor of the Japan Atomic Energy Research Institute at Tokaimura under the conditions mentioned above.

Table 1

Catalyst	NiO				Al_2O_3				SnO_2			
Addition	Li_2O		B_2O_3		Li_2O		B_2O_3		Li_2O		B_2O_3	
Irradiation*	bef.	aft.	bef.	aft.	bef.	aft.	bef.	aft.	bef.	aft.	bef.	aft.
Frequency factor ratio	1·7	1	1·1	1	1·6	1	1	2·5	1	2·9	1	2·5
Apparent activation energy (kcal./mole)	22	23	19	19	23	23	23	24	21	20	43	30

* bef. and aft. refer to before and after irradiation, respectively.

The catalytic activity measurements were made one month later by a flow method. The conversion ratio as a function of the reaction temperature is shown in Fig. 1. Scarcely any induced radioactivity was detected: nickel oxide system, 0·2 mr./hr. (γ-rays); aluminium oxide system, none; stannic oxide system, 0·4 mr./hr. (β-rays). On the assumption that the reaction is first-order, the apparent activation energy and the ratio of frequency factors before and after irradiation have been calculated and are shown in Table 1.

According to these results, the catalytic activity changes in every system: there is a small decrease with the nickel oxide system, an increase or decrease with the aluminium oxide system, and a remarkable increase with the stannic oxide system. Stannic oxide usually contains oxygen ion vacancies as an *n*-type semiconductor, and the number of these is readily increased by irradiation with alpha-particles which are produced by an (n, α) reaction with lithium-6 or boron-10 atoms. Nickel oxide contains excess oxygen ions as a *p*-type semiconductor and probably loses some of these on irradiation. The behaviour of the aluminium oxide system is probably due to its being an insulator.

The results of these experiments show that the larger the number of lattice defects, the more active is the semiconductor catalyst.

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A Simple Synthesis of Oxetanes

We would like to report a simple method of synthesizing oxetanes. Oxetanes have generally been prepared by a multi-step procedure involving the basic elimination of a halide or acyl radical. The syntheses are involved, and yields are low to fair. Our methods consists of dissolving a diol in a mineral acid, introducing the mixture into a heated solution of base, and distilling off the cyclic ether produced.

Using this method, we have prepared oxetane, 1-methyl oxetane and 2,2-dimethyl oxetane. Indications are that this synthetic method is generally applicable to the preparation of cyclic ethers, including oxiranes. Further work using this method is in progress.

Preparation of 2,2-dimethyl oxetane. 2 moles of sulphuric acid (111 ml., 96 per cent) were added to 2 moles of neopentyl glycol (208 gm.) and the mixture was stirred. The resulting solution was very viscous. A solution of 240 gm. sodium hydroxide in 107 ml. of water was brought to the boiling point in a 1-l., 3-neck flask equipped with a stirrer, dropping funnel and distilling head. The glycol solution was then added from the dropping funnel at such a rate as to maintain boiling. About 30 min. was required for this addition. Some heating of the dropping funnel with a burner was required to keep the viscosity of the glycol solution low enough for an adequate rate of flow. 120 ml. of distillate was collected, which separated into two layers. The lower aqueous layer was separated and partially redistilled to recover the organic material. The organic layer from the partial redistillation was combined with the original organic layer and dried with calcium chloride. The dried organic layer was further dried with calcium hydride and distilled.

The product boiling between 79° and 83° C. amounted to 49·2 gm., or 29 per cent.

For further characterization, the product was again redistilled from calcium hydride. The fraction boiling between 79·2 and 80·3° C. (uncorrected) at a pressure of 756 mm. mercury was collected.

The density was found to be 0·8272 gm./ml. at 25° C. The refractive index, N_D(25·1° C.), was 1·3956.

An infra-red spectrum was obtained, and found to be identical to one previously published[1], except that there was no indication of either carbonyl or hydroxyl in our sample.

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Cis–trans Isomerism of Thioindigo Dyes in the Solid State

As the result of some preliminary observations by Stearns[1], an extensive study was made by Wyman and Brode[2] of the absorption spectra of solutions of several thioindigo dyes in benzene and chloroform under various conditions of illumination. Evidence was obtained that in solution thioindigo and its derivatives exist in equilibrium as two forms (*cis* and *trans*), which give rise to separate absorption bands in the visible region. X-ray diffraction studies on crystalline thioindigo by Madame von Eller[3] suggest, however, that in the solid state the dye is present in the *trans* form. It is thought that the electrostatic attraction between slight positive and negative charges on neighbouring sulphur and oxygen atoms, respectively, maintains the thioindigo molecule in the *trans* configuration and prevents isomerization[4]. Presumably in some cases these attractive forces will be weakened by solvents or by substitution in the thioindigo molecule.

Some observations have recently been made of the absorption spectra of several thioindigo compounds in the form of solid transparent films on quartz prepared by vacuum deposition. The results suggest that where substitution would not be expected to diminish the electrostatic charges on the sulphur and oxygen atoms the *trans* compound appears to be the stable form in the solid state; but where reduction of these charges would be expected a mixture of *cis* and *trans* forms is found. Thus, as is seen in Fig. 1, solid films of thioindigo and 6 : 6′ dichlorothioindigo both exhibit a sharp absorption band in the visible region indicative of the sole presence of the *trans* isomer in the solid state. The presence of chlorine atoms in the 6 and 6′ positions in the thioindigo molecule should increase the negative character of the oxygen atom, and thus enhance the stability of the *trans* form. The introduction of methyl groups into the 4 and 4′ positions of this derivative of thio-

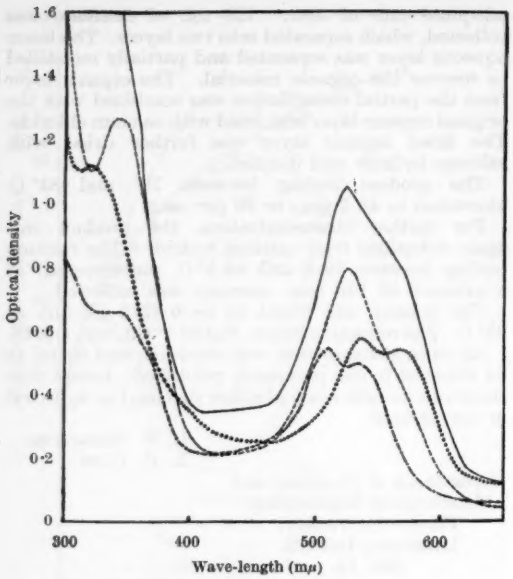

Fig. 1. The absorption spectra of solid films on quartz of thioindigo, ——; 6 : 6′ dichlorothioindigo, – – – –; 4 : 4′ dimethyl 6 : 6′ dichlorothioindigo, – · – · –; and 5 : 5′ dichloro 7 : 7′ dimethylthioindigo, ·····

indigo will, however, tend to reduce the electrostatic charge on these atoms and as might therefore be anticipated 4 : 4′ dimethyl 6 : 6′ dichlorothioindigo exists in the solid state as a mixture of *cis* and *trans* forms. A similar result is found with 5 : 5′ dichloro 7 : 7′ dimethylthioindigo. The proportion of *cis* form appears to be substantially in excess with the unsymmetrical 4 : 4′ dimethyl 5 : 6′ : 7 trichlorothioindigo, which is not illustrated in Fig. 1. It is also interesting to compare the spectrum of 6 : 6′ diethoxythioindigo with the analogous chlorine derivative. The former compound containing the electron-donating ethoxy group appears to exist as a mixture of *cis* and *trans* forms in the solid state, whereas the presence of the electron-attracting chlorine atom in 6 : 6′ dichlorothioindigo favours the stabilization of the *trans* form. Comparison of the hemithioindigo dye, 1′ acenaphthene 2 thianaphthene indigo with thioindigo is also valuable. The *trans* form of the latter has two pairs of sulphur and oxygen atoms available for stabilization, whereas the former has only one. The hemithioindigo dye[5] exists in the solid state as a mixture in which the *trans* form predominates.

When the thioindigo dyes are applied to cellulosic materials from solution in an alkaline reducing agent the leuco dye absorbed on the cellulose is incapable of existing in *cis* and *trans* forms because of the single-bond character of the central carbon atom. On oxidation of the dyeing the central double bond is reformed and isomerization of the dye is possible. Measurements of the absorption spectra of such dyeings on transparent cellulose film (deplasticized) have been made. The spectra of dyeings of thioindigo and 6 : 6′ dichlorothioindigo indicate only the presence of the *trans* form, whereas other substituted derivatives appear to be present in the dyed material in both *cis* and *trans* forms. In some cases (for example, 1′ acenaphthene 2 thianaphthene indigo[5] and 4 : 4′ dimethyl 6 : 6′ dichlorothioindigo) it is possible to increase the proportion of the *trans* form in the dyed cellulose by giving the latter a swelling treatment (for example, boiling with dilute soap solution), but in other cases (for example, 5 : 5′ dichloro 7 : 7′ dimethyl thioindigo and 4 : 4′ dimethyl 5 : 6′ : 7 trichloro thioindigo) the *cis* form seems remarkably stable to treatments of this kind. In both cases, however, the tendency is for the absorption spectrum of the after-treated dyeing to be very similar to that of the solid film of the same dye prepared by vacuum deposition. It would seem that many of the thioindigo dyes are present in a fairly stable mixture of *cis* and *trans* forms under the conditions of their commercial utilization.

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Crystal Structure of β-Glycine

It has been reported that glycine has three polymorphic forms: (1) an ordinary form, α, the crystal structure of which was determined in 1939 by Albrecht and Corey[1], a precise analysis having recently been carried out by Marsh[2]; (2) an unstable form β, first described by Fischer[3]—Bernal[4] has reported preliminary results of X-ray investigations of unit cell dimensions and space group symmetry, but the results are not conclusive; (3) the third form γ, found by me[5] in 1954, the crystal structure of which has recently been determined[6]. In this connexion, it seemed worth while to investigate the crystal structure of the β-form so that a comparison might be made between these three crystalline forms, especially of their hydrogen-bond systems.

A brief account of the structural determination will be given: the cell dimensions and space group

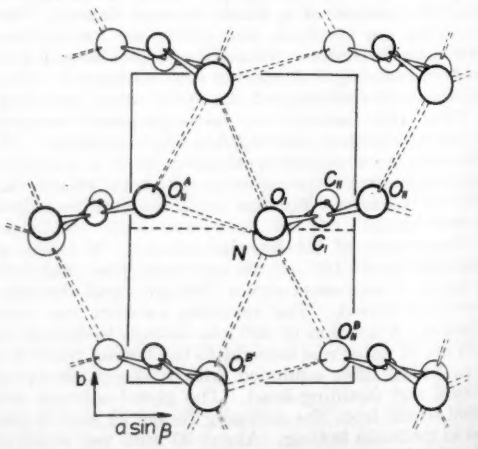

Fig. 1. A view of the β-glycine structure parallel to the *c*-axis, showing molecular layers connected by hydrogen bonds extending in the *b*-direction. Double dashed lines indicate hydrogen bonds

Table 1. Comparison of the Cell Dimensions and Space Groups of α-, β- and γ-Glycine

Form	Cell size (A.)				Volume	Space group	No. of molecules per cell	Molecular volume (A.³)
	a	*b*	*c*	*β*				
α*	5·102$_8$	11·970$_9$	5·457$_5$	111° 42·3′	309·7	$P2_1/n$	4	77·4
β	5·077$_4$	6·267$_6$	5·379$_9$	113° 12′	157·4	$P2_1$	2	78·7
γ†	7·037		5·483		235·1	$P3_1$ or $P3_2$	3	78·4

* See ref. 2. † See ref. 6.

are shown in Table 1 together with those of α- and γ-glycine.

Intensities were recorded using a single-crystal diffractometer[7]. A trial structure similar to that of α-glycine was adopted. Refinement of the structure was carried out using both (*h*0*l*) and (0*kl*) difference Fourier projections. The (0*kl*) difference map gave clear indication of the anisotropic thermal motions of the atoms along the *b*-axis. Taking into account these anisotropies, the structure was further refined. The resulting reliability factors were 0·06 and 0·05 for (*h*0*l*) and (0*kl*) reflexions, including contributions from hydrogen atoms.

The arrangement of the molecules of glycine in the β-form is indicated in Fig. 1, which shows that it consists of hydrogen-bonded molecular layers extending parallel to the (010) plane. These layers have the same configuration of molecules as the α-form.

It is of interest to compare the packing of these layers in the two types of glycine. These forms differ in the hydrogen-bond systems between layers. In β-glycine, those single layers connected geometrically by the two-fold screw axis are held together by hydrogen bonds extending in the *b*-direction. In α-glycine the nitrogen atom is buried within the double layer in such a way that very close contact of these two layers occurs.

The values for the bond-lengths and bond-angles of the molecule are very close to those found in the α-form. However, the departure of the nitrogen atom from the plane containing the carboxyl group by 0·59 A. is somewhat larger. In Table 2 the bond-lengths and bond-angles are given together with N..O interatomic distances and C—N..O angles between neighbouring molecules.

Table 2. Bond-Lengths and Bond-Angles in β-Glycine

Length (A.)	Angle (deg.)	Length (A.)	Angle (deg.)
N—C$_{II}$ 1·48	C$_I$—C$_{II}$—N 111	N..O$_I^C$ 2·76	C$_{II}$—N..O$_I^C$ 113
C$_I$—C$_{II}$ 1·52	O$_I$—C$_I$—C$_{II}$ 118	N..O$_{II}^A$ 2·82	C$_{II}$—N..O$_{II}^A$ 115
C$_I$—O$_I$ 1·24	O$_{II}$—C$_I$—C$_{II}$ 116	N..O$_I^{B'}$ 3·00	C$_{II}$—N..O$_I^{B'}$ 145
C$_I$—O$_{II}$ 1·25	O$_I$—C$_I$—O$_{II}$ 126	N..O$_{II}^B$ 3·01	C$_{II}$—N..O$_{II}^B$ 83

A more detailed account of this work will be published elsewhere.

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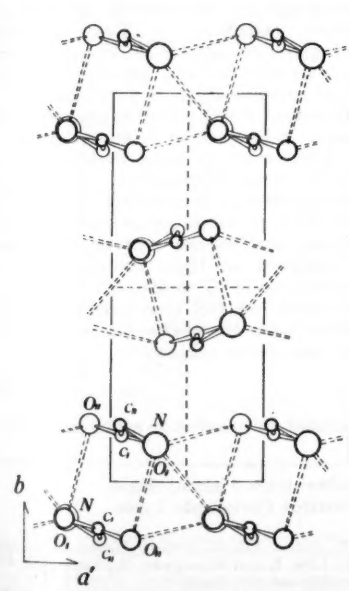

Fig. 2. A view of the α-glycine structure parallel to the *c*-axis, showing molecular double layers held together by hydrogen bonds (after G. Albrecht and R. B. Corey, ref. 1)

Circular Gas Chromatograph

It is reasonable that a gas chromatographic apparatus can be arranged in a circular form. Fig. 1 shows a chromatographic column connected head to tail. In operation, the carrier gas is brought to a desired initial pressure using the stopcock arrangement that is also utilized for sampling. The pump in the circuit is used to circulate the carrier gas previously introduced. Simple laboratory peristaltic-type pumps have been found satisfactory for circulating the gas stream. A bleed stream of carrier gas from a separate source is used in the reference side of a resistance-wire thermal-conductivity detector. The columns are packed with crushed insulating brick of conventional size. Temperature control is accomplished by either liquid or air baths.

The stationary liquid phase normally used in gas chromatography has a low volatility relative to the compounds being separated. With the circular apparatus, the liquid need not have a low volatility. Fig. 2 shows the record for separation at room temperature of acetone, boiling point 56·2° C., and normal hexane, boiling point 68·7° C., using methanol, boiling point 64·7° C., as the liquid phase. Acetone travels more slowly than hexane due to selective adsorption and is separated after passage through half the circular column. During the time required for acetone to make an additional circuit of the column, the hexane has gone through the detector two additional times.

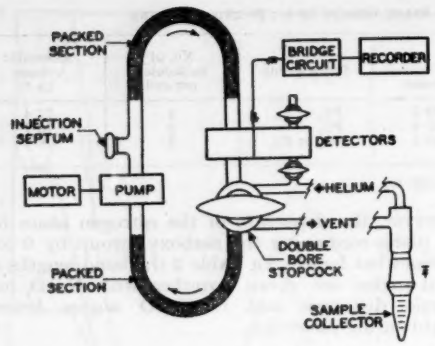

Fig. 1. Schematic diagram of circular gas chromatograph

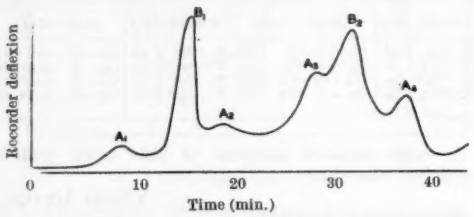

Fig. 2. Injection of a mixture of *A*, *n*-hexane, and *B*, acetone, using a methanol column

In a separate experiment, the retention time of normal heptane is 4·5 min. for the solid support coated with methanol and 0·5 min. for the support with no liquid present under the same conditions. Therefore, the methanol clearly is acting as a partitioning liquid.

There are several advantages in being able to use volatile partitioning liquids. A wider range of liquids can be utilized. In addition, non-analytical chromatographic applications are often of more interest if there is less difference in the boiling points of the liquid phase and the partitioned components. Experimentally, volatile partitioning liquids can be added through the sample injection septum and allowed to become distributed uniformly *in situ*.

The dead volume in the detector cell and mixing action of the pump cause a loss in efficiency as compared to a single pass through a comparable straight column. Column efficiency is evaluated by conventional theoretical plate calculations. However, using 2,4-dimethylsulpholane as the liquid phase in a circular 10-ft. column, the efficiency was found to increase linearly with the number of cycles up to a length of column equivalent to 150 ft. This arrangement, therefore, offers a way to operate the equivalent of a long column at a low and more efficient ratio of the initial pressure to that at the outlet.

On a preparatory scale, use of the circular arrangement conserves solid support, liquid phase, carrier gas, and the energy required for thermostatic control. The optimum length of column for separation can be selected by choosing the proper number of cycles the materials are circulated. The equipment can be made automatic.

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BIOCHEMISTRY, PHYSIOLOGY and MEDICAL SCIENCES

Starch Gel Electrophoresis Studies on Abnormal Proteins in Myeloma and Macroglobulinæmia

We have investigated by starch gel electrophoresis[1], using a technique described in a previous paper[2], 28 sera from patients with multiple myeloma, 13 from patients with macroglobulinæmia, 4 sera from cases with atypical dysproteinæmia. In every case a characterization of abnormal serum components was carried out previously, using free-boundary electrophoresis[3], analytical ultracentrifuging[4], agar gel and immuno-electrophoresis[5].

Concerning plasmocytoma, in so-called 'γ-myeloma' (according to free-boundary electrophoresis at *p*H 8·6, ionic strength 0·1 in veronal buffer), the sera demonstrated in starch gel either a high 'fast' or a high 'slow-γ' component. On sedimentation diagrams, a 6 *S* component was seen in most cases.

In cases of 'β-myeloma' in starch gel, abnormal components, as shown by quantitative results, are located in various positions, but in the α-β and slow-α 2 zone.

In a typical β-myeloma, starch gel electrophoresis shows three abnormal components (as compared with normal serum). The euglobulinic fraction of the serum similarly shows three components. In one case of α-myeloma the abnormal component is in the post-albumin zone.

Concerning macroglobulinæmia, sera with high levels of heavy components (mainly 17 *S*), ascertained as β-2 *M* globulins by immuno-electrophoresis, yield, in starch gel, no characteristic patterns. That may be due (Silbermann, H. J., personal communication) to the non-displacement of macroglobulins in the gel.

Four cases of 'dysproteinæmia were selected from 136 patients with 'myeloma-like' patterns. These cases are characterized by the absence of bone marrow plasmocytosis, negativity of X-ray investigations, but β-2 *M* globulins and/or heavy components (by sedimentation) were lacking. Electrophoretic pattern in starch gel resembles that of myeloma.

The influence of size of molecule may be emphasized in the case of β-lipoprotein in starch gel[6].

In the present study some findings seem to be related to the same phenomenon; for example, an abnormal α-component (mobility 4 cm.^{2}/volt/sec. 10^{-5} at *p*H 8·6) shows in starch gel an increase in the post-albumin zone, and 92 per cent of the serum components migrated as light components by ultracentrifugating the (4 *S*) component.

In conclusion, we feel that investigation of dysproteinæmias using electrophoresis in starch gel may be a very promising subject.

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The Iron–Protein Link in Hæmoglobin and Myoglobin

It is generally considered that the hæm iron in hæmoglobin and myoglobin and their derivatives is bound to the apoprotein through histidine imidazole groups, although there is some uncertainty[1] whether the stronger of the two postulated imidazoles (ascribed $pK_1 = 5{\cdot}3$ in ferrihæmoglobin and ferrimyoglobin[2]) has been so identified.

The *p*H stability curves of native and recombined horse ferrimyoglobin are shown in Fig. 1, obtained after addition of solutions of the native protein and of the components of the recombined protein to a series of phthalate and phosphate buffers (*p*H 2·3–7·0, $\mu = 0{\cdot}05$, $T = 21°$ C.). The solutions were stood for 16 hr. at 1° and then 2 hr. at 21° before reading the absorbances at 408·5 mμ, the Soret *p*H 7·0 peak. Curves of similar type and approximate position were obtained for ferrihæmoglobin, measured at 405 mμ. When hæmatin or ætiohæmatin combines with native globin or apomyoglobin at *p*H 6–7, a comparable major increase in Soret peak absorbance occurs[3] between *p*H 4 and 6 (Fig. 1). The curves therefore appear to indicate dissociation of the hæmatin iron from specific groups in the apoprotein.

A reversible equilibrium between 'acid hæmatin' and ferrihæmoglobin exists[4] within the *p*H range 3·0–6·0, and while the curves of Fig. 1 and similar ones obtained by removal of hæmatin with acetone[5] do not exactly fit dissociation curves of acids with single equilibrium constants, they could represent such curves partly masked by overlapping contributions from other linkages, such as hæmatin propionyl – apoprotein or iron – anion ligand.

Since at *p*H 5·3 only a very small decrease in Soret peak absorbance occurs and only a very small fraction of the hæmatin is extracted by acetone[5], the specific groups indicated, which I consider to be those binding the hæmatin iron to the apoprotein, are unlikely to be the postulated imidazoles of $pK_1 = 5{\cdot}3$. A *pK* of this value could be related to dissociation of hæmatin propionyl. Rather it would appear that groups of the nature of aspartyl β- or glutamyl γ-carboxyls ($pK \approx 4{\cdot}7$) are ionizing. Potentiometric titration studies of horse carboxyhæmoglobin[6] have also suggested carboxyl groups (of *pK* approximately this value) linked to the hæm, while iron–carboxyl linkages have been considered to occur in recombined hæmoglobin[1] and, on evidence from both spectrophotometric and enzymatic activity studies, in the related hæmoprotein, horse-radish peroxidase[7].

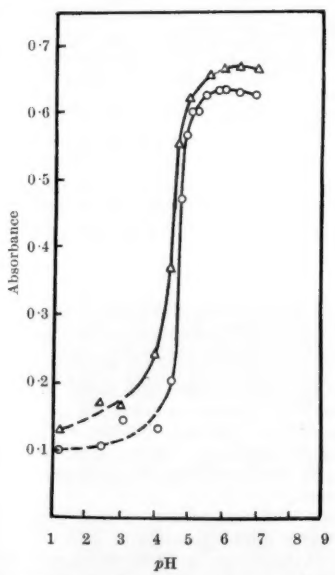

Fig. 1. *p*H stability curves of native and recombined horse ferrimyoglobin in the *p*H range 1–7 from the absorbances at 408·5 mμ. Native ferrimyoglobin (—○—○—), 0·1 ml. $9{\cdot}3 \times 10^{-5}$ *M* solution + 10 ml. buffer; recombined ferrimyoglobin (—△—△—), 0·05 ml. $1{\cdot}8 \times 10^{-4}$ *M* protohæmatin in 0·01 *M* sodium hydroxide + 0·10 ml. $2{\cdot}1 \times 10^{-4}$ *M* apomyoglobin solution + 10 ml. buffer. Buffers: *p*H 1·2, hydrochloric acid; 2·3–6·2, phthalate; 6·5–7·0 phosphate; $\mu = 0{\cdot}05$. Temperature of measurement, 21° C. Path-length, 4 cm.

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Chromatographic Behaviour of Human Albumin labelled with Iodine-131

The *in vivo* behaviour of plasma proteins labelled with iodine-131 prepared by methods developed in this laboratory[1,2] is almost identical with that of the corresponding proteins labelled with carbon-14 by the biosynthetic procedure[3,4]. Human albumin preparations iodinated by these methods have a chromatographic distribution similar to that of unlabelled albumin when analysed on anion exchange columns of diethylaminoethyl cellulose (Fig. 1). Similar results have been obtained on cation exchange columns of carboxymethyl cellulose. On the other hand, commercially iodinated human albumin (Abbotts, Chicago), which has been extensively used in clinical studies of albumin turnover, has recently been shown to have a chromatographic distribution markedly different from native albumin[5]. It is now recognized that preparations of protein labelled with iodine-131 may be adversely affected by a variety of factors, including the method of fractionation, the technique of iodination[1], preliminary heat treatment of the protein[6] and self-irradiation[7]. Investigation of these variables has shown that by far the greatest changes in chromatographic behaviour of albumin labelled with iodine-131 result from self-irradiation.

Human albumin prepared by ion exchange chromatography[8] was iodinated at a mean ratio of less than 1 atom per molecule using the iodine monochloride method recently described by McFarlane[2]. The effect of self-irradiation was investigated in solutions containing 2–3 mgm. albumin and 500–700 μc. of iodine-131 per ml. Solutions were stored at 3° C. and tracer amounts added to human serum at intervals after labelling. Irradiation-levels between 40 and 85 k.rads produced a progressive displacement of the radioactive from the native albumin (Fig. 2). The electrophoretic mobility on paper of these irradi-

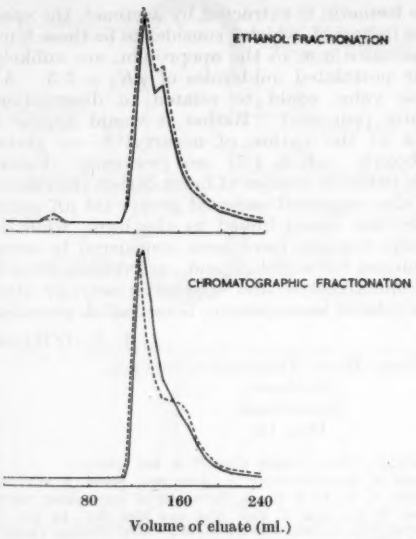

Fig. 1. Chromatographic analysis of human albumin prepared by ethanol fractionation and ion exchange chromatography. Iodinated albumin (0·5 mgm.) was added to 50 mgm. of the corresponding unlabelled albumin before dialysis. The analysis was performed on diethylaminoethyl cellulose columns using a gradient elution with phosphate buffer *p*H 7·1, 0·005 *M* and 0·30 *M* sodium dihydrogen phosphate. Protein distribution is indicated by solid lines and radioactivity by broken lines

ated proteins remained unchanged although as previously shown[7] albumin 'tailing' was increased by irradiation at doses above 45 k.rads.

In contrast to the marked effect of irradiation only minor differences in chromatographic behaviour were induced by altering the methods of albumin fractionation and iodination. Human albumins prepared by zone electrophoresis, ion exchange chromatography, ethanol fractionation[8] and crystallization from concentrated salt solution (Behringwerke, Marburg-Lahn) were examined. After iodination[2] these proteins were added to the corresponding unlabelled albumin so that labelled molecules constituted not more than 1 per cent of the protein analysed. The various albumin preparations were not chromatographically identical, but in all of them the distribution of labelled and unlabelled molecules was similar. Results obtained with two of these preparations are shown in Fig. 1. Albumin iodinated using hypochlorite[10] showed a second minor peak of radioactivity displaced beyond the native albumin. Preliminary heat treatment of human albumin in the presence of stabilizers did not alter the chromatographic pattern.

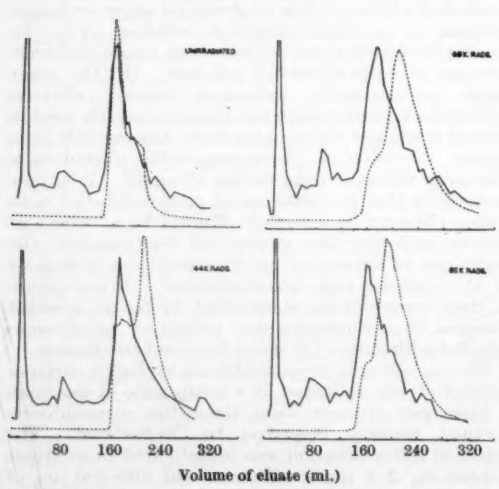

Fig. 2. Effect of irradiation on the chromatographic behaviour of human albumin labelled with iodine-131 and prepared by chromatography. Tracer amounts of the labelled solution which contained 650 μc. iodine-131 per ml. and 2·5 mgm. albumin per ml. were added to normal human serum immediately after iodination and after storage for 7, 14 and 22 days, which provided self-irradiation doses of 44 k.rads., 68 k.rads, and 85 k.rads respectively. Chromatography was carried out as in Fig. 1. Protein distribution is indicated by solid lines and radioactivity by broken lines

It is concluded that human albumin can be prepared and iodinated without gross alteration of its behaviour on the ion exchange columns used in this investigation. Similar results have been obtained with rat and rabbit albumins. The chromatographic dissociation of native human albumin and that labelled with iodine-131 recently reported[6] can be reproduced in dilute protein solutions by self-irradiation at levels above 40 k.rads. Chromatographic analysis appears to be the most sensitive physicochemical method available for detecting undesirable alterations in samples of albumin labelled with iodine-131 for metabolic studies.

I am grateful for helpful discussions with Dr. A. S. McFarlane and Dr. R. R. Porter. Dr. P. S. Charlwood and Prof. H. E. Schultze kindly supplied samples of human albumin.

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1,6-Di-(2-Bromoethylamino)-1,6-Dideoxy-D-Mannitol Dihydrobromide: a New Cytostatic Agent

Recently it was reported that 1,6-di-(2-chloroethylamino)-1,6-dideoxy-D-mannitol dihydrochloride[1] shows significant tumour inhibitory effect[2]. This compound ('Degranol', 'Mannomustine') has been employed in the treatment of malignant hæmatological diseases[3].

Since the chlorine atoms of this compound show comparatively slight reactivity, and since the cytostatic effect in the group of mustard nitrogen derivatives increases in general parallel to the reactivity of halogen atoms of the 2-halogenethylamino group[4], in further experiments we replaced the chlorine atoms of 1,6 - di - (2-chloroethylamino)-1,6-dideoxy-D-mannitol dihydrochloride with the more active bromine atoms. The synthesis of this bromine derivative (1,6-di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol dihydro-

bromide) was performed by analogy with the (1,6-di-(2-chloroethylamino)-1,6-dideoxy-D-mannitol dihydrochloride from the 1,6-diethylenimino-1,6-dideoxy-3,4-*iso*propylidene-D-mannitol with concentrated aqueous hydrobromic acid. The former compound crystallizes from *iso*propanol, or aqueous dioxan in colourless needles which are easily soluble in water: m.p. 204–205° C. while decomposing; $[\alpha]_D^{20} = +10{\cdot}6°$, water, $c = 1{\cdot}0$. (Found: C 21·4, H 4·6, Br 57·4. $C_{10}H_{24}O_4N_2Br_4$ requires C 21·6, H 4·4, Br 57·5.)

As animal experiments presented in the next communication prove, 1,6-di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol dihydrobromide is active as expected in much smaller dose than the chlorine derivative and its therapeutic effectiveness is more favourable.

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Effect of 1,6-Di-(2-Bromoethylamino)-1,6-Dideoxy-D-Mannitol Dihydrobromide on Tumours of Laboratory Animals

The chemotherapeutic effect of the new compound 1,6-di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol dihydrobromide (see preceding communication) has been tested on different tumours of laboratory animals (Table 1). The compound was administered once daily in succession intraperitoneally after the appearance of palpable inoculated tumours. In comparison we tested the effect of the chlorine derivative ('Degranol', 'Mannomustine')[1] in the treatment of the same tumours.

From the results it is obvious that the 1,6-di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol dihydrobromide inhibits the growth of rat and mouse tumours to a greater extent than 'Degranol' (Fig. 1).

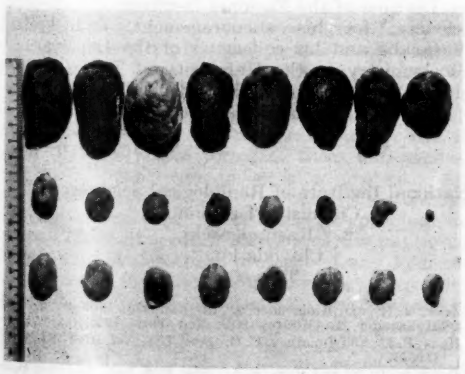

Fig. 1. Inhibition of the growth of the subcutaneous form of Yoshida sarcoma by 1,6-di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol dihydrobromide (DBM) (*R*13) and the chloride derivative (BCM)
Top, control; middle, DBM; bottom, BCM

Table 1. Degree of Inhibition of the Growth of Rat and Mouse Tumours by 1,6-Di-(2-bromoethylamino)-1,6-dideoxy-D-mannitol Dihydrobromide (DBM) (*R* 13) and the Chloride Derivative (BCM) ('Degranol')

Tumours tested	Degree of inhibition (per cent) DBM (*R* 13)	BCM ('Degranol')
Guérin rat carcinoma	89	
Guérin rat carcinoma	64	54
Yoshida rat sarcoma subcutaneous form	93	84
Ehrlich mouse carcinoma	39	21
S_{37} mouse sarcoma	53	29
Amytal mouse ascites (ref. 2) sarcoma	44	19

For the treatment of mice with tumours, 3–5 mgm./kgm. daily dose is necessary, and for the treatment of tumour-bearing rats 2–3 mgm./kgm. is sufficient. In contrast, the daily therapeutic dose of 'Degranol' corresponds to 20 mgm./kgm. for mice and 15 mgm./kgm. for rats.

When given 34 times in daily succession, the therapeutic dose to rats, in the bone marrow a slight decrease of leucopoietic elements is to be observed. Study of the blood reveals moderate leucopænia with more marked lymphopænia. Microscopically, in the spleen and lymph nodes atrophy of the follicles can be found.

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Biochemical Heterogeneity of the Ribonucleic Acid synthesized by *Escherichia coli B* after Irradiation with Ultra-violet Light

It is well known that the effects of radiation on the biosynthesis of ribonucleic acid and protein are reduced slightly under conditions in which the synthesis of deoxyribonucleic acid is inhibited almost completely[1]. There have been few investigations of the ribonucleic acid synthesized after irradiation.

It has recently been suggested by Haas and Doudney[2,3], however, that mutation of *Escherichia coli* is induced by ultra-violet light through the incorporation of modified nucleic acid precursors into the ribonucleic acid, resulting in modifications of the latter. It is thus of interest to investigate whether any chemical or biochemical modifications occur in ribonucleic acid synthesized after irradiation.

An overnight culture of *E. coli B*(*H*) was inoculated in *tris*–glucose medium and harvested by centrifugation when growth was in the logarithmic phase. The cells collected were washed once with physiological saline and resuspended in the same saline. Half the suspension was irradiated with ultra-violet light. Irradiation was carried out by germicidal lamp ('Toshiba' *GL*-1502, 15 W.) for 60 sec. at a distance of 30 cm. The other half was used, unirradiated, as control. Both irradiated and control cells were collected and resuspended in *tris*–glucose medium

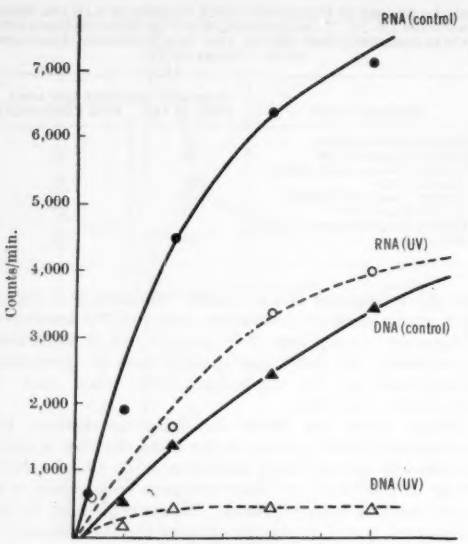

Fig. 1. The incorporation of phosphorus-32 into the ribonucleic acid and deoxyribonucleic acid fractions of *Escherichia coli B(H)*, with and without irradiation with ultra-violet

containing phosphorus-32 and incubated at 37° C. From time to time samples were withdrawn and the phosphorus-32 incorporated was fractionated by the procedure of Schmidt and Thannhauser. The incorporation of phosphorus-32 into the ribonucleic acid and deoxyribonucleic acid fractions after irradiation with ultra-violet is shown in Fig. 1. The survivals were about 10^{-5}, and the total amount of phosphorus-32 incorporated into the ribonucleic acid fraction was about 50 per cent after 60 min. as compared to the control. Inhibition of incorporation of phosphorus-32 into the deoxyribonucleic acid fraction was nearly complete.

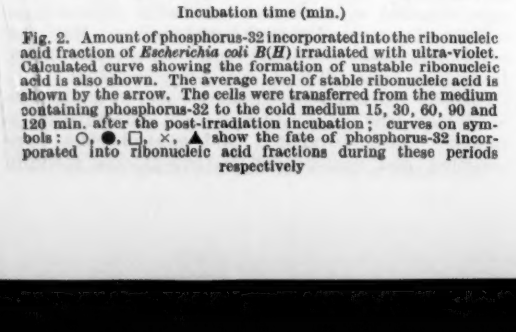

Fig. 2. Amount of phosphorus-32 incorporated into the ribonucleic acid fraction of *Escherichia coli B(H)* irradiated with ultra-violet. Calculated curve showing the formation of unstable ribonucleic acid is also shown. The average level of stable ribonucleic acid is shown by the arrow. The cells were transferred from the medium containing phosphorus-32 to the cold medium 15, 30, 60, 90 and 120 min. after the post-irradiation incubation; curves on symbols: ○, ●, □, ×, ▲ show the fate of phosphorus-32 incorporated into ribonucleic acid fractions during these periods respectively

Fig. 2 shows the phosphorus-32 incorporated in the ribonucleic acid fraction after the cells were removed from the medium containing phosphorus-32 at various times, washed, and reincubated in *tris*–glucose medium which contained no phosphorus-32.

Part of the phosphorus-32 incorporated into the ribonucleic acid fraction for incubation periods longer than about 30 min. has a tendency to be released from that fraction during re-incubation. But as shown in Fig. 2, the final level of phosphorus-32 in ribonucleic acid remains nearly constant regardless of the time when the cells are transferred to the isotope-free medium. When incubation with phosphorus-32 is shorter than 30 min., the amount incorporated reaches the final level described above and is conserved thereafter.

Ribonucleic acid phosphorus was conserved in unirradiated control cells as reported previously[4].

These results suggest that although the incorporation of phosphorus-32 into the ribonucleic acid fraction may occur in *E. coli* after irradiation with ultra-violet light, the fraction is composed of two parts, one stable and the other unstable. In addition, the incorporation into the unstable fraction seems to occur after a time-lag of 30 min. following irradiation (calculated curve is shown in Fig. 2). Since such a loss of phosphorus-32 from the ribonucleic acid fraction was not observed when the cells were incubated in the medium containing phosphorus-32 for 3 hr. after irradiation, and since the incorporation of phosphorus-32 was observed even when the isotope was added after incubation for 2 hr., the phosphorus in the unstable ribonucleic acid fraction seemed to be characterized by its continuous replacement.

The formation of unstable ribonucleic acid has been reported in some cases[5,6] and the degradation of these ribonucleic acids was found to be restored by the addition of chloramphenicol. The effects of the addition of chloramphenicol (40 μgm. per ml.) and dinitrophenol (10^{-3} *M*) and that of the omission of glucose from the medium were tested in our system but none of these agents was observed to have any effect on the loss of ribonucleic acid phosphorus.

The chemical difference between normal ribonucleic acid and that synthesized after irradiation with ultra-violet light is now under investigation, and a detailed report will be published elsewhere.

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Activation of Amino-Acids in Relation to the Synthesis of Silk Proteins

THE 'activation' of the carboxyl groups in amino-acids is often assumed to be an indispensable preliminary stage in the biosynthesis of protein. The rate of the activation is known to vary with various amino-acids. The question arises whether there is any relation between the rate of activation of an amino-acid and its content in the protein. The silk-glands of the silkworm lend themselves particularly well to the study of such a problem since they produce two well-defined proteins, the amino-acid composition of which is known. While the posterior silk-gland produces 'fibroin', which contains 42 per cent of glycine and 28 per cent of alanine, the middle silk-gland produces 'sericin' containing 30 per cent of serine[1]. We have studied the activation of a number of amino-acids present in these two proteins of the silkworm caterpillars (*Bombyx mori* L.). The '*p*H 5 enzymes' were obtained from the posterior and middle silk-glands as well as from the hæmolymph. The hydroxamic method was used to determine the rate of the activation of the carboxyl groups in the amino-acids. The composition of the enzymatic mixture was approximately the same as that referred to by Davie, Koningsberger and Lipmann[2]. The results which we obtained are given in Table 1.

Table 1. THE RATE OF THE AMINO-ACID ACTIVATION IN SILK-GLANDS AND IN THE HÆMOLYMPH OF SILKWORM CATERPILLARS. THE RESULTS ARE EXPRESSED AS MEANS WITH THE STANDARD DEVIATION OF THE MEAN

Amino-acids	μmole of hydroxamates/1 mgm. of protein/hr.		
	Posterior silk gland	Middle silk gland	Hæmolymph
Alanine	0·068 ± 0·03	0·088 ± 0·03	0·085 ± 0·04
Glycine	0·038 ± 0·00	0·073 ± 0·01	0·057 ± 0·02
Glutamic acid	0·031 ± 0·02	0·258 ± 0·07	0·105 ± 0·03
Histidine	0·098 ± 0·01	0·286 ± 0·15	0·060 ± 0·02
Serine	0·318 ± 0·05	0·168 ± 0·04	0·079 ± 0·02
Tryptophan	0·623 ± 0·10	0·406 ± 0·21	0·071 ± 0·03
Tyrosine	0·600 ± 0·19	0·370 ± 0·18	0·150 ± 0·06

The two amino-acids which showed the highest rate of activation were tryptophan and tyrosine. Yet it is known that there are only traces of tryptophan in the proteins of the silk. Glycine, on the other hand, showed the lowest rate of activation in spite of its high concentration in the silk proteins. Thus no relationship could be established between the rate of the activation of amino-acids as measured by the hydroxamic method and their actual concentration in the proteins. We then decided to investigate the possibility that the activation of glycine proceeds mainly through transacylation. In view of the high rate of activation of tryptophan and tyrosine it seemed that the active forms of these two amino-acids might participate in such a process. An attempt was therefore made to observe activation of glycine in the presence of either tryptophan or tyrosine. Chromatographic analysis of the mixtures, however, did not reveal the presence of any hydroxamic acids other than those of tryptophan or tyrosine. As regards the possibility that glycine activation occurs outside the silk-glands, we found that in the hæmolymph the activation is negligible. Thus the question as to how glycine is introduced in the course of silk protein synthesis still remains open. Our results, however, suggest that the incorporation of amino-acids into protein must occur by means other than the activation of the carboxyl groups.

A detailed report of this work will be published in the *Acta Biochimica Polonica*.

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Casease in *Entamoeba histolytica*

CASEASE, the proteolytic, casein-hydrolysing enzyme, has been reported in many bacteria. It has not hitherto been detected in the protozoan, *Entamoeba histolytica*. In earlier studies, Nakamura[1] reported the absence of casease in certain strains of the amœbæ. It was thought that the failure to demonstrate the enzyme might have been due to the comparatively large amounts of casein in the assay plates. Therefore, the experiments were repeated using a modification of the same method but incorporating smaller concentrations of casein in the test plates.

The amœbæ were cultured in coagulated whole egg slants overlaid with Ringer–liver extract solutions. Cultures 72 hr. old were pooled and washed four times in saline solution. The supernatant from the final washing was also tested for enzymatic activity; any remaining associated bacteria from the amœba stock cultures would be contained in this supernatant. In addition, the associated bacteria were assayed for casease activity in the absence of the amœbæ.

The method consisted of placing large drops of material to be assayed on the surface of 1·0 per cent agar plates containing 0·2 per cent casein, incubating for 12 hr. at 20–25° C., and flooding the agar plates with a mercuric chloride–hydrochloric acid solution (a protein-precipitating agent). Clear areas in the opaque casein-agar plates indicated zones of casein hydrolysis.

Two strains of *E. histolytica* (large race *HUS*-105 and small race Washington) hydrolysed casein. However, the supernatant from the fourth washing and the cultures of the associated bacteria did not hydrolyse casein. The amœbic casease was destroyed by heating at 65° C. for 5 min. but not by a temperature of 55° C. for 5 min. The enzyme activity at varying *p*H values was studied, and it was found to be active between *p*H 5 and *p*H 8. Thus, another proteolytic enzyme is established in *E. histolytica*. These experiments on the proteolytic activity of the amœbæ[2–4] may eventually yield clues on the mechanisms of pathogenicity of this important parasite.

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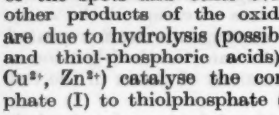
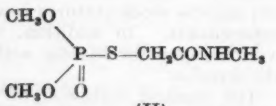
Mode of Action and Biological Properties of the S-(Methylcarbamyl) Methyl O,O-Dimethyl-Dithiophosphate

Previous investigations have demonstrated that S-(methylcarbamyl) methyl O,O-dimethyl-dithiophosphate (I), which possesses a peculiar insecticidal and systemic activity, very effectively controls the olive fly (*Dacus oleae* Gmel.)[1,2], the olive moth (*Prays oleellus* F.)[3], the cherry fruit fly (*Rhagoletis cerasi* L.)[4] and many other important pests. It was of interest, therefore, to investigate the metabolic behaviour and biological properties of this insecticide.

Experiments carried out by means of paper chromatography have demonstrated that oxidation of compound (I) by potassium permanganate and by hydrogen peroxide produces some derivates. Among them one component has been isolated, purified (by means of 100-tube Craig countercurrent distribution) and identified: the S-(methylcarbamyl) methyl O,O-dimethyl-thiolphosphate (II). The low R_F values of the spots and other evidence suggest that the other products of the oxidation of compound (I) are due to hydrolysis (possibly O,O-dimethyl dithio- and thiol-phosphoric acids). Metallic ions (Fe^{3+} Cu^{2+}, Zn^{2+}) catalyse the conversion of dithiophosphate (I) to thiolphosphate (II).



(I)



(II)

The same transformation has been shown to occur, at least partially, *in vivo* in plants such as broad beans, after root absorption of the insecticide, and in cherries, picked from sprayed trees; and *in vitro* in animal tissues, by incubating the insecticide (I) with mouse liver. Other derivatives (possibly products of hydrolysis), besides the thiol metabolite (II), from hydrogen peroxide oxidation of compound (I), were not found in the paper chromatographed tissues.

A gradual reduction in the amount of compound (II), obtained by chemical synthesis and applied to broad beans and cherries in the same conditions as insecticide (I), was demonstrated by paper chromatography and bioassay, but no evidence was obtained on the conversion of this compound to other derivates.

Toxicological researches indicate that the thiolphosphate (II) is a much stronger esterase inhibitor than the dithiophosphate (I): 185 times as effective as bovine cholinesterase inhibitor and 883 times as effective as house fly (*Musca domestica* L.) cholinesterase inhibitor. Nevertheless, compound (II) is only four times as toxic as (I) to mice by oral administration.

The insecticidal activity of both substances (I) and (II), tested on 11 species of insects, is nearly equal; the small differences being related to species and stages of insects and methods of testing. This suggests also that insects may metabolize the dithiophosphate (I) to thiolphosphate (II). On the other hand, the two substances possess different acaricidal activities: compound (II) is about 38 times as toxic as (I) to adults of *Paratetranychus pilosus* Can. and Fanz.

Finally, studies on systemic properties have been conducted. Both products, when applied to roots, stems or leaves of beans are absorbed and translocated to other parts of the plants in amounts lethal to the test mites (adults of *Tetranychus telarius* L.) feeding on untreated parts of the same plants. Furthermore, both compounds penetrate from the outside to the inside of fruits and exert a lethal effect on some species of fruit-eating larvæ.

Detailed results will be published elsewhere.

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α-Tocopherol and Hyaluronidase *in vivo*

The description of exudative diathesis in chicken by Dam[1] indicates a considerable degree of capillary damage. In a further publication[2] he attributed this to a deficiency of α-tocopherol.

Reports[3,4] on the interaction of α-tocopherol and hyaluronidase suggested to me that, apart from its anti-oxidant activity, α-tocopherol might be involved in the protection of inter-cellular cement substance. Thus, in the condition described by Dam, the exudation could be due to the effect of hyaluronidase acting on the inter-cellular cement substance of the capillary walls and surrounding supporting tissues without the restraining influence of adequate α-tocopherol.

We divided twelve chickens into three groups of four each. Group 1 was fed a basal ration low in vitamin E and containing 17 per cent protein, 3·3 per cent fat, 1·3 per cent calcium, 0·8 per cent phosphorus and 0·5 per cent added sodium chloride; group 2 received the same ration plus 14 I.U. vitamin E/lb. fed as added 'Rovimix' (F. Hoffman, La Roche et Cie.); group 3 a normal commercial ration. After 5 weeks on these diets two birds in each group were injected intraperitoneally with a commercial brand of hyaluronidase 'Rondase' (Evans Medical Supplies, Ltd.). Each bird received 6,000 I.U. daily for 7 days. On the eighth day the birds were killed together with the control uninoculated birds, and Table 1 shows the results of post-mortem examination.

Table 1

Group	Control birds (no hyaluronidase)	Birds injected with hyaluronidase
1	Slight hæmorrhages in muscles	Hæmorrhages and advanced exudative diathesis
2	Normal	Normal
3	Normal	Slight hæmorrhages in muscles

These results indicate that *in vivo* β-tocopherol can act as a regulator of hyaluronidase activity.

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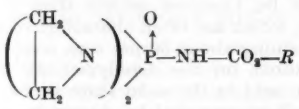
'Dual Antagonists'; Alkyl N-(*bis*-(ethylenimido)phosphoro)-carbamates; a New Series of Anti-Tumour Agents

THE concept of combination chemotherapy in the treatment of neoplastic diseases has been receiving considerable attention during the past few years. Some see the only theoretically possible solution to the problem of cancer chemotherapy in the simultaneous use of several synergistic drugs blocking several consecutive, and/or alternative metabolic pathways, while others vigorously object to this thesis, from practical considerations or disappointing experiences.

One of our three collaborating research groups has been particularly interested in the chemotherapeutic potentialities of 'dual antagonists'[1], that is, chemical compounds incorporating the structural features of two different antimetabolites into a single molecule. 'Dual antagonists' are designed to synchronize the action of the synergistic components and thus overcome differences in absorption, distribution, or elimination that would negate or weaken any potentiation arising from simultaneous block of metabolic pathways at several points. If two inhibitors, directed against the same biochemical mechanisms or cellular structures but possessing different degrees of selectivity, are coupled chemically, the more selectively localizing component may prevail in directing the distribution of the molecule as a whole. As a result, the less selective (but often more potent) component may reach concentrations at the desired point of attack that could not be attained by the free (uncoupled) inhibitor below its toxic dosage. In particularly favourable cases, both synergistic components may be released at the desired point of attack gradually and simultaneously, providing for a prolonged local action.

Compound 1 of this communication unites the *bis*-(ethylenimido)-phosphoro radical, a bifunctional group known to have biological 'alkylating' activity, through an amide linkage to urethane, an antimetabolite of nucleic acid biosynthesis[2,3]. The carcinostatic effect of urethane is reported to be synergistic with the similar effect of biological alkylating agents[4].



1, $R = C_2H_5$ ('*AB*-100')
2, $R = CH_3$ ('*AB*-101')
3, $R = CH_2—C_6H_5$ ('*AB*-103')

In compounds 2 and 3, the same alkylating radical is linked to methyl and benzyl carbamate, respectively. Although the latter carbamates, as such, are not known to be effective antimetabolites, it is thought possible that when linked to the electron-attracting phosphoro-group they may split to yield the same active intermediate as urethane.

Compounds 1 and 2 were synthesized by treating dichloro*iso*cyanatophosphine oxide[5] first with ethyl alcohol (or methyl alcohol) and then with ethylenimine in the presence of a hydrogen chloride acceptor. Compound 3 was prepared by heating compound 1 in the presence of benzyl alcohol. All three compounds are white solids which can be crystallized from a mixture of benzene and cyclohexane: m.p.: 1, 88–90°; 2, 119–21°; 3, 134–35° C.

Compounds 1 and 2 are readily soluble in water, but decompose slowly in aqueous solution. In the animal experiments reported below, these two compounds were used in freshly prepared aqueous solutions, while compound 3 was injected in aqueous suspension or, intramuscularly, in peanut oil.

Acute intravenous toxicity tests in *ICR/Ha* Swiss mice gave the following *LD*50 values (mgm./kgm.): 1, 69·4; 2, 62·3; 3, 80·0. The corresponding values after intraperitoneal and subcutaneous administration are the same or only slightly higher, indicating rapid absorption. All deaths occurred between 4 and 9 days after the single injection. Histopathological studies indicated lymphoid involution.

Only a brief outline can be given here of the anti-tumour evaluation of compounds 1, 2 and 3; details will be published elsewhere. Eleven mouse and rat neoplasms were used in this work, and the new compounds were directly compared with nitrogen mustard under a variety of experimental conditions. In doses of equal toxicity, the three compounds were superior or equal to nitrogen mustard. In most cases, compound 3 demonstrated the highest activity, followed by compounds 1 and then 2.

In mice, all three compounds were active in the 'standard' sarcoma 180 test; average *T/C* ratios of 32 per cent by tumour diameter measurement, and 3–4 per cent (0·03–0·04) by tumour weight, were obtained. In different types of experiments with sarcoma 180, *ICR/Ha* Swiss mice were inoculated with known numbers of ascites tumour cells (*a*) subcutaneously and (*b*) intraperitoneally; in all experimental situations, the new compounds caused highly significant inhibitions of (*a*) tumour growth, and (*b*) ascites formation, respectively. Compounds 1 and 3 were also highly effective against Ehrlich ascites tumour and adenocarcinoma 755. In a number of transplanted leukæmias, definite prolongation of life was obtained with compounds 1 and 3; in others, prolongation of mean life-span was of borderline or no statistical significance. Many animals in the latter groups lived much longer than any untreated animals, but many died earlier, presumably because of drug toxicity in a state weakened by disease. This results in increased standard deviation. In *DBA*/2 mice inoculated with leukæmia *L*1210, four animals (out of 50) treated with compound 3 survived 90 days after inoculation and showed no sign of disease when killed and autopsied after this time. In our hands, no other chemotherapeutic agent produced similar apparent cures in any mice inoculated with this leukæmia. In *C3H* mice with 'spontaneous' mammary tumours, highly toxic doses of compound 3 (which actually killed all animals within 2 weeks) caused regression of existing tumours; lower, non-toxic doses inhibited tumour growth.

In rats, all three compounds completely inhibited the growth of Walker carcinosarcoma 256 tumours, at well-tolerated dosage-levels. In Dunning rat leukæmia, all three compounds, administered only during the first 12 days after implantation of the tumours, caused complete inhibition of tumour growth and apparently cured all animals. When they were re-inoculated with the tumour after 42 days, all developed tumours and died with leukæmia. In the control animals, tumours appeared on the eighth day after implantation and all animals died with leukæmia on the eighteenth–nineteenth day. Even when the treatment was delayed until the sixteenth day after tumour implantation, when the average

size of tumour had reached 3·5 cm. and the white-cell count was about 70–90,000, compounds 1 and 3 still caused regression of all visible tumours; however, in this case, the tumours re-appeared after the treatment was discontinued, and the animals died.

Twenty-five patients with various advanced neoplastic diseases have been treated with compound 1. There was a remarkable absence of gastro-intestinal side-effects. The only side-reaction resembling those of known alkylating agents was depression of bone marrow. It is too early to evaluate the therapeutic results in these patients, although there are indications of anti-tumour effects.

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Fluorescence of Tissue Culture Cells stained with Acridine Orange

Armstrong[1] has shown that biological fluorochrome acridine orange under controlled conditions of *p*H differentiates in fixed tissues betwen deoxyribo- and ribo-nucleic acids, the former showing green fluorescence and the latter red. Schummelfeder, Ebschner and Krogh[2], who examined the nature of this specificity, have shown that acid or heat treatment of fixed tissue, prior to its staining by acridine orange, changes the green-yellow fluorescence of the nuclear matter to a copper-red colour similar to that given by ribonucleic acid in the cytoplasm. From their observations the authors suggested that the green and red shades of fluorescence of acridine orange are associated with high and low molecular-weight forms of the nucleic acids. The deoxyribonucleic acid within the nucleus, however, is characterized by: (*a*) high degree of polymerization and (*b*) high level of orientation, which includes its double-stranded form and the structural organization within the chromosomes. The inquiry conducted by Schummelfeder *et al.* does not indicate the level of depolymerization necessary for the change in fluorescence. It does not also completely eliminate the significance of orientation in the specificity of greenish fluorescence usually shown by chromatin matter within the nucleus stained by acridine orange.

We have made observations on the fluorescence given by some tissue-culture cells stained by acridine orange prior to, and after, their exposure to different dosages of X-rays. Intestine, HeLa, HeLL and conjunctiva cells were grown in basal Eagle's medium on slips in flat test-tubes. After 24 hr. incubation, the slips were transferred to standard veronal buffer (*p*H 7·3) and irradiated with X-rays (International G.E.C., 200 kV., 100 m.amp.; 160 r./min.) up to a maximum dose of 4,000 r. The cells were fixed immediately in 3 per cent formalin, then transferred to a buffer medium of the desired *p*H, and later stained with acridine orange solution in the same buffer at *p*H 3–6 and concentration 0·05 per cent. The non-irradiated cells were given the same treatment as irradiated ones. The fluorescence of the stained material was observed with blue-violet excitation by using the mercury arc lamp with Reichert blue filter No. 8027 at the source and minus blue filter No. 8006 at the eyepiece.

In the non-irradiated cells all the nuclei showed green fluorescence with nucleoli yellow. The cytoplasm showed crimson red fluorescence. On X-ray irradiation the red fluorescence of the cytoplasm did not show much change except slight intensification. The green-yellow fluorescence of the nuclei also did not show much change until the irradiation dose exceeded 2,000 r. There was, however, a marked change from green towards red when the dose was increased above 2,200 r. and no nucleus with a green fluorescence was left over on the slip, when the dose was greater than 3,200 r. Thus the change of nuclear fluorescence did not appear to be a gradual process but was distinctly confined to a narrow dose-range between 2,000 r. and 3,000 r. These results indicate that in the mechanism that shifts the observed nuclear fluorescence within cells, some step or steps that respond to a cumulative or multihit action of ionizing radiations are involved.

The depolymerization of deoxyribonucleic acid by ionizing radiations has been studied in the solution state by Butler[3], Conway[4] and Daniel, Scholes and Weiss[5]. Their observations indicate that in the aqueous solutions the immediate action on depolymerization of deoxyribonucleic acid by X-rays is very feeble although more significant 'after-effects' are seen. No results concerning the dose effect relationship for the after-effects are yet available. Under the conditions of the present experiments, however, depolymerization studies in the solid state of deoxyribonucleic acid seem to be more important; for the deoxyribonucleic acid within the cells is considered to be localized within their chromosomal structures, which are often characterized by their gel state containing about 30 per cent solid matter[6].

Observations on the depolymerization of deoxyribonucleic acid in the solid state by ionizing radiations have been reported by Alexander and Stacey[4]. Their studies do not indicate a multi-hit mechanism for the breaks in the main chain of deoxyribonucleic acid. Besides, on the basis of their results, an estimate of the drop in the average molecular weight of deoxyribonucleic acid at 3,000 r. does not amount to even 1 per cent. We are therefore tempted to conclude that the green fluorescence of deoxyribonucleic acid stained by acridine orange is associated with some more labile character, such as its native state, not affected by formalin fixation, rather than simply its high polymer nature.

Beers, Hendley and Steiner[7] have recently shown the formation of two types of complexes between acridine orange and nucleic acids. Complex I involved the bases and inter-nucleotide phosphates of ribonucleic acid. Complex II, however, involves the terminal phosphates of both ribo- and deoxyribo-nucleic acid. They further state that the green fluorescence of nuclei is the result of the formation of complex II with deoxyribonucleic acid and the red

fluorescence of ribonucleic acid is due to the formation of the mixture of complexes I and II involving greater take-up of the dye. The critical level of irradiation observed by us might be causing some intramolecular disorientation of deoxyribonucleic acid, involving inter-nucleotide bonds, so exposing additional sites for subsequent binding with acridine orange .

It may be noted that Puck, Marcus and Cieciura[8], in their experiments on clonal growth of mammalian cells by feeder layer technique, observed complete suppression of multiplication among the population of 2×10^5 HeLa cells with an X-ray exposure of 4,000 r. They also found that these irradiated feeder cells, though unable to multiply themselves into colonies, showed otherwise active metabolism.

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Phenolic Acids as Growth and Germination Inhibitors in Dry Fruits

The presence and chemical composition of substances in fleshy fruits which inhibit germination and growth have been studied by several workers[1–3]. On the other hand, the chemical nature of the inhibitors in dry pericarps is but little known[4,5]; thus their detailed examination seemed to be justified.

The water- and ether-soluble inhibiting substances in fruits of twenty-four species (for example, capsulas, legumes, siliquas) were examined with paper chromatography together with bio-assay, then chemically identified. The identification was made on the basis of R_F values, ultra-violet fluorescence, colour reactions and comparison with synthetic compounds.

According to the results inhibitors are present in all the fruits examined. The inhibiting substances are localized in two main areas in the chromatograms. In the inhibiting zone, between R_F 0·C and 0·35, many benzoic- and cinnamic-acid derivatives of lesser activity were found, such as large-molecule tannic acids, protocatechuic-, caffeic-, chlorogenic-, ferulic-, *p*-coumaric- and *p*-oxy-benzoic acids, and an unknown phenol derivative. From the inhibiting zone between R_F 0·55 and 0·75, strongly active salicylic acid and, in seme cases, two unknown cinnamic acid derivatives were demonstrated. It may be supposed that isomers of the above-enumerated substances are also present on the chromatograms.

It is remarkable that all inhibitors, chemically identified from dry fruits, are phenolic acids or their depsides and polydepsides. These substances occur in various combinations and quantitative proportions in the different fruits, but are not specific. Comparing the inhibitors in dry fruits with those demonstrated from fleshy ones, a considerable conformity can be seen. This fact supports our earlier assumption that the occurrence of phenolic acids as inhibiting substances are common in higher plants.

The greater part of the inhibitors is washed out of the fruits which remain on the trees until the spring. The rate of the leaching depends very much on the structure of the pericarp and the chemical nature of the inhibitors. The results prove that storage in dry conditions has no effect on the quantity and quality of inhibitors in the fruits.

Details of this work will be published elsewhere.

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Dose–Response Relationship in Radiation Leukæmia: the Marking Probit

Linearity (or non-linearity) of the leukæmogenic potency of radiations has been discussed extensively in the recent literature[1,2]. Experimental results are usually presented by plotting incidence in percentages versus dose on an arithmetical scale. A regression curve is then fitted for assessing a correlation between these variables. The form of a dose–response curve is apparently attracting more attention than the nature of the variables involved.

In any sample of susceptible individuals, some develop leukæmia as a response to irradiation at a given dose, others do not. The development of leukæmia is clearly an all-or-nothing effect, that is, a quantal response. This implies a distribution of susceptibilities within the sample. Susceptibility stands for our ignorance of all the factors upon which the development of leukæmia is dependent. From theoretical statistics, however, we know that quantal effects exhibit a sigmoid dose – response curve. Adequate statistical treatment therefore requires probit analysis. Probit regression curves fit experimental results on radiation leukæmias in *C* 57 *BL* mice[3].

The second variable is the dose. It may be satisfactorily defined by four parameters: magnitude, rate, fractionation and duration. Incidence of leukæmia has been shown to vary with these dose factors[4]. For probit transformation the distribution of susceptibilities must be approximately normal, or normalized by metametric transformation of dose (dosage). For *C* 57 *BL* mice, normalization can be effected by expressing the susceptibilities in terms of the logarithm of the dose; but nothing has been published about an appropriate dosage for radiation leukæmias in humans. In any event, the assumption

that incidence is independent of dose factors is most probably inaccurate; and incidence in percentages and dose on an arithmetical scale are irrelevant variables.

An alternative can be introduced by assuming a linear correlation and looking for variables that possibly fit it. This approach has led us to define the marking probit as a working hypothesis. It is assumed that both lethal and leukæmogenic effects of radiation are independent quantal responses distributed in a population of hæmatopoietic mother-cells present in any irradiated mouse. This independence is supported by experimental evidence[5]. Let PM be the probability of any mother-cell showing the leukæmogenic response (marking) and PL the probability of the lethal response (death). The probability PA of a leukæmia being initiated in any irradiated mouse is assumed to be equal to the proportion of marked surviving mother-cells. This proportion is an estimate of the combined probability $PM(1 - PL)$. Hence $PA = PM(1 - PL)$. The probability of acute radiation death in mice and rats is related to the degree of hæmatopoietic destruction as shown by leucocyte counts[6,7]. To a first approximation, PL may be therefore estimated from the acute mortality percentage. Furthermore, the probability of any mouse developing a leukæmia PC (observed incidence in the sample) is dependent upon PA and the chances of own survival $(1 - PL)$. Thus $PC = PA(1 - PL) = PM(1 - PL)^2$. Hence $PM = PC/(1 - PL)^2$.

Values for PM have been calculated from Kaplan's and my own results. From Figs. 1 and 2 it can be seen that PM may be normally distributed on dose or logarithm of the dose. It is therefore called the 'marking probit', as percentages may be expressed in terms of probits. Available data do not provide statistical control of the best fit. It is interesting to note, however, that marking probits are independent of dose factors. They are exclusively a function of total dose. It may be concluded that successive doses are additive for the initiation of the leukæmogenic process but not for the ultimate development of radiation leukæmia. The distribution of marking probits suggests that leukæmogenesis may require more than a single critical molecular event, although such an event may be the initiating agent.

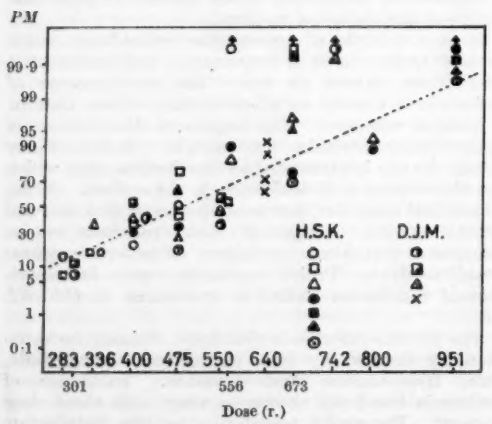

Fig. 1. Correlation between probability of a mother-cell showing the leukæmogenic response (PM) and total dose.
PM calculated from Kaplan's data: ○, single dose; □, 2 doses at one-day interval; △, 4 doses at one-day intervals; ●, 8 doses at one-day intervals; □, 4 doses at four-day intervals; ▲, 4 doses at eight-day intervals; ⊙, 4 doses at sixteen-day intervals.
PM calculated from my results: ◑, 2 doses at five-day intervals; ◪, 2 doses at five-day intervals + cysteamine; ◬, 2 doses at five-day intervals + cystamine; ×, 4 doses at seven-day intervals, with or without cystamine

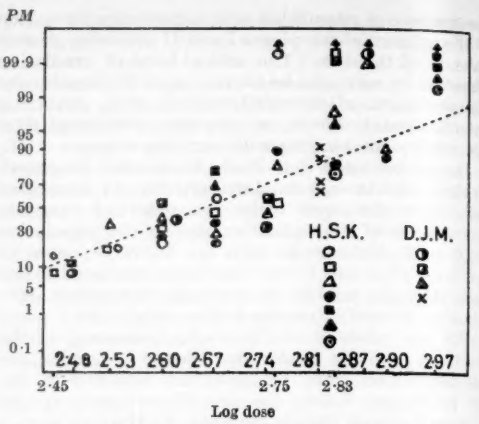

Fig. 2. Correlation between PM and logarithm of the dose

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Assimilation of Ammonia Nitrogen by Rumen Bacteria

Ammonia is always present in the rumen liquor of sheep[1] and the concentration varies with the kind of protein in the ration, but the addition of starch-rich foods such as maize meal or flaked maize to high-protein rations depresses the concentration[2–4].

The reason for this effect is not entirely clear; it is well known that the non-protein nitrogen of foodstuffs can, in part, substitute for protein in the ration, and this has led to the use of urea as a protein substitute in feeding cattle and sheep. There is evidence that nitrogen derived from urea can be assimilated by rumen bacteria when starch or maltose are present[5,6]. Assimilation of nitrogen-15 by mixed rumen organisms in the form of ammonia has been found[7], and variants of *Lactobacillus bifidus* isolated from the rumen are reported to assimilate ammonia nitrogen from the media[8].

The experiments summarized here were undertaken to examine the effects of different rations on the net changes of the ammonia content of rumen liquor and to obtain further information on the effects of starch on the possible assimilation of ammonia nitrogen.

The rumen liquor of sheep fitted with permanent rumen cannulæ and fed on various rations was withdrawn and incubated under carbon dioxide for 2–4 hr. at 37° C. Ammonium chloride was added to one of duplicate flasks to increase the initial concentration

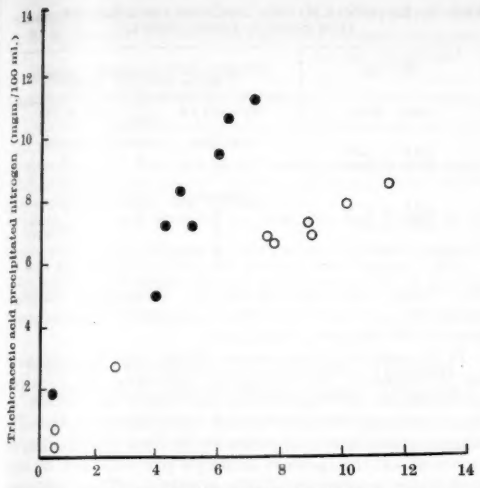

Fig. 1. The ammonia nitrogen lost from the media with peptone ● and without peptone ○ in relation to the nitrogen gained in the trichloracetic acid precipitate measured by direct determination using one culture incubated for periods of 12–96 hr.

of ammonia nitrogen by 40 mgm./100 ml. The total content of ammonia increased during incubation in the rumen liquor of sheep fed on grass or hay or sheep fed on hay with protein supplements. It decreased when the donor sheep were fed on hay with either fodder beet or a mixture of flaked maize and maize gluten meal. In the latter circumstances, the extent of the loss was variable and very occasionally did not occur. This was so if liquor was drawn before the first morning feed or if the sheep had a poor appetite, as occurred occasionally with the flaked maize ration. The loss of ammonia nitrogen from the rumen liquor of sheep fed the flaked maize ration was accompanied by an increase in the trichloracetic acid precipitate, and the use of ammonium chloride enriched with nitrogen-15 showed that ammonia nitrogen was concentrated in this precipitate. We are grateful to Dr. E. I. McDougall of this Institute for determining the concentration of nitrogen-15 in the various fractions before and after incubation.

A similar medium to that previously used[8] was devised containing starch and glucose in which ammonium chloride provided 87·1 per cent of the total nitrogen, *l*-cysteine 12·7 per cent and B vitamins 0·2 per cent. The whole was made up in a phosphate buffer, and trace elements were added. The media also contained acetate, a small quantity of citrate and 0·075 per cent agar. For solid media, the agar concentration was increased to 1·3 per cent. Liquid medium was gassed with oxygen-free carbon dioxide immediately after inoculation. Plates were incubated anaerobically under a gas phase of hydrogen containing 5 per cent carbon dioxide. Rumen liquor diluted in phosphate buffer was used for inoculating solid media and colonies were picked from plates and transferred to liquid media. Organisms isolated in this manner grew well. Isolates were obtained mainly from sheep fed on hay or hay and the flaked maize mixture with or without groundnut meal. *l*-Cysteine was essential for rapid growth. Replacement with thioglycollate allowed a less vigorous growth except when casein hydrolysate or methionine was added. *l*-Ascorbic acid or sulphide were ineffective even with methionine or casein hydrolysate. Growth did not occur in the presence of *l*-cysteine if ammonium chloride was substituted by sodium chloride. The majority of isolates were slender branching rods; but some coccal forms were also isolated. The general properties of all isolates were that starch and glucose were fermented with the formation of acetic and lactic acids and ammonia nitrogen was assimilated. The addition of peptone to the media caused more vigorous growth but ammonia nitrogen was still assimilated but to a less extent (Fig. 1).

The behaviour of cultures, however, was not always consistent, and after several subcultures some cultures produced ammonia when grown in the media with peptone, but after several further subcultures regained the property of assimilating ammonia nitrogen.

Additional examination of 28 isolates of the rod type showed that they all possessed the characters of lactobacilli; the sugars fermented were the same as those found for *Lactobacillus bifidus*[9]; the quantities of acetic and lactic acid formed were close to the ratio of 2 : 1; the lactic acid formed was found by Dr. T. M. Sutherland of this Institute to be the L(+) form. The morphological characters were also compatible with those described for *Lactobacillus bifidus*.

Table 1. The Mean Logarithm of I + the Count, when the Count is given in millions/ml., for Sheep fed on Hay (*H*), Hay and Groundnut Meal (*H* + *G*), Hay with the Flaked Maize Mixture (*FM*) and Hay with the Flaked Maize Mixture and Groundnut Meal (*FM* + *G*)

	H	*H* + *G*	*FM*	*FM* + *G*	S.E. of difference (3 d.f.)
'Normal'	0·84	0·79	1·96	1·56	± 0·74
	0·81		1·76		± 0·52
'Peptone'	1·24	1·19	2·88	2·08	± 0·44
	1·21		2·48		± 0·31

Systematic plate counts of organisms in rumen liquor that would colonize on the media with or without peptone were made using eight sheep, pairs of which were maintained on one of the following rations: hay, hay with groundnut meal, hay with the flaked maize mixture and hay with the flaked maize mixture and groundnut meal. Four counts from each sheep were made over a period of four months and two sheep on different diets were sampled on each occasion. It was possible to eliminate differences between occasions when the results were analysed. Table 1 summarizes the results for the logarithm of I + the count with these occasional differences eliminated. It will be seen that using the medium with peptone ('Peptone') the rations containing the flaked maize mixture produced higher counts than the rations without this mixture ($P < 0.05$). There is the same tendency with the counts made on the medium ('Normal') without peptone. The results with the 'Normal' media, however, are not significant, and this is probably due to one sheep in which no colony formation at all occurred on two occasions. The derived mean counts are given in Table 2. We are indebted to A. W. Boyne of this Institute for the statistical analysis of the results.

Table 2. The Mean Counts derived from Table 1 in millions/ml.

	H	*H* + *G*	*FM*	*FM* + *G*
'Normal'	11	10	151	60
'Peptone'	29	26	1,260	200

As colonies picked from 'peptone' plates had the property of assimilating ammonia nitrogen when grown in liquid medium, it appears as if the 'peptone'

counts are more representative of the numerical importance of bacteria with this property than the more selective medium without peptone.

These experiments support the hypothesis that the depression in concentration of ammonia nitrogen that occurs when a starch-rich food is added to a high-protein ration may be due, in part, to an increase in the concentrations of bacteria that can assimilate ammonia nitrogen.

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β-Globulin Polymorphism and Early Fœtal Mortality in Cattle

Six β-globulin types have been found in British breeds of cattle by starch-gel electrophoresis[1]. Mating data showed that the six types represent the individual homozygotes and heterozygotes of three β-globulin alleles, β^A, β^D and β^E. Five of these six types were seen independently by Hickman and Smithies[2], who postulated a similar genetic mechanism.

It has been found that the proportion of the two possible types of offspring from some reciprocal matings is apparently influenced by the maternal genotype. Thus, from certain matings involving only the alleles β^A and β^D equal numbers of offspring like or unlike the mother (with respect to β-globulin genotype) would be expected. However, a consistent excess of offspring like the mother was obtained from such matings in both Friesian and Ayrshire cattle (Table 1). Although several of the calves in the results were sired by the same bull the effect was not correlated with particular bulls. Because of the practice of early disposal of bull calves from dairy herds the data relate only to female calves. It is not yet known if the same phenomenon occurs with male offspring.

In similar matings involving the allele β^E a preponderance of like-mother offspring was found when this allele was in the fathers' genotype only (Table 2). From the corresponding reciprocal matings where the mothers' genotype included β^E a consistent lack of β^E offspring was found.

Table 1. Reciprocal Matings showing an Excess of Like-Mother Offspring in Two Breeds of Cattle

Mating	Offspring (female calves from cows mated with A.I. bulls)			
	Friesian		Ayrshire	
Dam Sire	Like dam	Like sire	Like dam	Like sire
$\beta^A\beta^A \times \beta^A\beta^D$	19	11	0	0
$\beta^A\beta^D \times \beta^A\beta^A$	13	8	12	3
$\beta^D\beta^D \times \beta^A\beta^D$	17	9	3	1
$\beta^A\beta^D \times \beta^D\beta^D$	32	25	1	0
Totals	81	53	16	4
Significance	$\chi^2 = 5{\cdot}85$; $P = 0{\cdot}01$–$0{\cdot}02$		$\chi^2 = 7{\cdot}2$; $P = 0{\cdot}01$–$0{\cdot}001$	

Table 2. Reciprocal Matings involving the Allele β^E (Results from Several Breeds Pooled)

Mating	Offspring (female calves from cows mated with A.I. bulls)	
Dam Sire	Without β^E	With β^E
$\beta^A\beta^A \times \beta^A\beta^E$	Like dam 6	Like sire 5
$\beta^D\beta^D \times \beta^D\beta^E$	22	11
$\beta^A\beta^E \times \beta^A\beta^A$	Like sire 5	Like dam 1
$\beta^D\beta^E \times \beta^D\beta^D$	8	2

It is unlikely that these effects can be explained by differential production of gametes, by selective fertilization, by differential mortality in calfhood or by unwitting selection by the dairy farmer. The only simple explanation appears to be that the chances of survival of the bovine embryo are affected by the β-globulin genotype of the mother. Thus embryos differing in genotype from the mother appear to be less compatible with the mother than those of like type, except where the maternal genotype includes β^E. Then there seems to be antagonism between β^E dam and β^E embryo causing a dearth of β^E offspring. In this connexion it is significant that β^E is the least frequent of the three alleles in each breed examined, and is in fact absent in Jersey, Guernsey and South Devon cattle. A gene at a disadvantage in a balanced polymorphic system must have some counterbalancing advantage or it would be eliminated by natural selection. Whatever the nature of this advantage for β^E it is presumably greater for northern breeds of British dairy cattle than for southern because the β^E frequency increases steadily northwards[1].

Because of the low frequency of β^E the losses due to the postulated antagonism between β^E dam and embryo would be numerically small. However, the losses due to the lack of unlike-mother offspring (Table 1) from matings involving β^A and β^D could be quite important. Assuming that one-third fewer unlike-mother offspring are produced, it can be calculated that when the frequencies of β^A and β^D are 0·5 and β^E nil, only 83 per cent of conceptions would result in viable offspring if there were no other causes of prenatal loss. This percentage will increase as the disproportion between the frequency of β^A and β^D increases.

Robinson has used data from several sources to compute the estimated extent of prenatal loss in the cow[3]. He concludes that 10 per cent of services to cows in œstrus do not result in fertilization, while the products of conception from 27 per cent die during the first three months of gestation. Data published by the Milk Marketing Board[4] indicate a consistent loss of about 12 per cent of fœtuses between the first and third months of pregnancy. The loss was unaffected by season for three years, although the overall conception-rate showed seasonal variation. This 12 per cent loss is in close agreement with the estimated average of 86–88 per cent viability due to mother – fœtus β-globulin incompatibility.

From these results one would expect a greater percentage of viable offspring from crosses between homozygous bulls and cows of the same genotype, β^E individuals excluded, than from other crosses. Data to check this are now being collected.

I am indebted to Drs. P. M. Sheppard and A. W. H. Braden for helpful suggestions and criticism.

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Juvenile Hormone in Thymus, Human Placenta and other Mammalian Organs

The development of methods for extracting and assaying the juvenile hormone of insects[1] has encouraged a search for the same biological activity in animals other than insects. Schneiderman and Gilbert have reported the first progress in this direction. Ether extracts of various invertebrates, including Hydrozoa, Polychaeta, Oligochaeta, Holothuroidea, Balanoglossida and Decapoda, give positive tests for juvenile hormone when assayed on pupæ of the silkworm, *Antheraea polyphemus*[2]. Equally surprising is the demonstration of juvenile hormone activity in certain crude aqueous extracts of bovine adrenals[3].

These extraordinary findings suggested the need for a more complete census of the distribution of juvenile hormone activity among mammalian tissues and organs. Our present purpose is to report that most, and perhaps all, mammalian tissues contain demonstrable amounts of a substance the biological activity of which in the insect assay is indistinguishable from that of juvenile hormone.

Our initial studies were performed on 1-day-old rats which were anæsthetized and blended at room temperature in 3 : 1 diethyl ether–ethanol. After washing with water and evaporation of the solvent, a golden oil was obtained which gave positive tests for juvenile hormone.

Afterwards, we took advantage of the fact that desiccated pulverized preparations of individual bovine organs are commercially available from the H.M. Chemical Co., of Santa Monica, California, and the Nutritional Biochemicals Corporation of Cleveland, Ohio. 50-gm. samples of ten of these pulverata were blended and extracted at room temperature with diethyl ether, and the extracts washed several times with water. After evaporation of the solvent, the oily extracts were tested for juvenile hormone activity by a modified version of the 'wax test' described by Schneiderman and Gilbert[2,3]. In brief, a zone of cuticle, about 1 mm. square, was excised from the thoracic tergum of a previously chilled *A. polyphemus* pupa. The oily extract was applied topically to the exposed epidermis and the latter then capped and sealed with melted wax. If the extract contains juvenile hormone, a patch of pupal cuticle forms under the wax wound during the pupal–adult development[2,3].

Positive tests were obtained for extracts of the following pulverata: thymus, bone marrow, placenta, ovary, corpus luteum and adrenal cortex. Liver, testis, kidney and spleen gave negative tests.

The extracts were chromatographed on alumina columns by precisely the same techniques that fractionate juvenile hormone in extracts of insect material. The individual fractions were dissolved in a small volume of peanut oil and tested by injection into *A. polyphemus* pupæ. After this purification, all extracts, including those that were formerly negative, gave positive test for juvenile hormone activity. Among the ten pulverata, thymus gave extracts of highest activity and adrenal cortex of next highest.

These results were confirmed and extended in the preparation of very active fractions from fresh calf thymus and liver, beef tenderloin and fresh human placenta. Positive tests were also obtained from preparations of deep-frozen pituitaries of sheep.

In contrast to these uniformly positive findings on mammalian organs, we have failed to detect any trace of activity in wheat-germ oil, soy-bean oil or extracts of dried brewer's yeast.

Extracts of commercial lard gave negative tests. However, we can report that substantial activity is found in purified extracts of ordinary heavy cream and in products prepared from cream. In contrast to this, extracts of powdered skimmed milk are inactive.

In summary, the picture that takes shape reveals a very broad distribution in the mammalian body of a factor which is indistinguishable from the juvenile hormone of insects. In view of the extraordinary biological activity of this hormone on the growth, metamorphosis and aging of insects, it seems important to decide whether the juvenile hormone may play a part in mammalian physiology or whether its presence in higher forms is something of a biochemical curiosity.

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Recovery of Injected Progesterone and its Relation to the Onset of Human Labour

The conception that progesterone is the hormone responsible for the maintenance and therefore secondarily also for the onset of labour is based on several important findings: the indispensability of the corpus luteum for pregnancy in the rabbit[1]; the extraction of the effective substance from corpora lutea[2]; the role of progesterone in the implantation and early development of the fertilized ovum[3]; the excretion of progesterone as urinary pregnanediol and the relation between pregnanediol output and the prognosis of pregnancy[4]; finally, the elucidation of the mechanism of the endocrine control of the pregnant rabbit uterus[5–7].

In the rabbit the indispensability of progesterone for the maintenance of gestation is thus definitely proved. In the human, however, the role of progesterone in the maintenance and termination of pregnancy is much more obscure: it is not possible to prevent premature labour[8] and to prolong pregnancy[9] by means of progesterone administration; the increasing

sensitivity of the myometrium to oxytocin at the end of gestation is not suppressed by progesterone injection[10]; the level of serum progesterone[11] and the excretion of pregnanediol[12] do not drop until after delivery.

It has, however, been reported[13] that in the first half of normal human pregnancy more than 20 per cent of administered progesterone is excreted as urinary pregnanediol, while less than 20 per cent is excreted in pregnancies which end in spontaneous abortion. A similar relation between myometrial reactivity and progesterone recovery was suggested by recent experiments made by me[9] on legal abortions by means of intra-amniotic formalin injections. Therefore, I supposed that such a relation may also exist in other cases of reactive myometrium, for example, prior to labour. No earlier investigation of progesterone recovery at the end of gestation has been reported.

Twenty-five normal and healthy women in different stages of pregnancy received 200–400 mgm. progesterone ('Proluton', Schering) as a single intramuscular injection. The urine was collected in 24-hr. samples, generally for 10 days, that is, 2–3 days before and 6–7 days after progesterone injection. Pregnanediol was determined according to Jensen's method[14]. By this method only pregnanediol (free and conjugated) is determined. The average pregnanediol excretion during 2–3 days before progesterone injection was taken as pre-injection blank. If labour occurred earlier than 3 days after progesterone injection, the period of observation was assumed to be too short; hence these cases were excluded.

In the first 36 weeks of pregnancy the recovery of injected progesterone was found to vary between 19 and 38 per cent with an average of 27 per cent (Table 1).

Table 1. Recovery of Progesterone as Urinary Pregnanediol before the Thirty-sixth Week and during the Two Last Weeks of Pregnancy

Length of gestation (weeks)	No. of cases	Progesterone recovery (per cent)	
		Range	Average
< 36	10	19–38	27
39–40	15	0–13	3

The large amount of endogenous pregnanediol excreted at the end of gestation and the great daily variations in the excretion cause some difficulties in calculating the recovery of progesterone during this period. In order to facilitate the calculation of recovery, large doses of progesterone were given (in most cases 400 mgm.). If, as in the first 36 weeks, 20–40 per cent of exogenous progesterone had been excreted (that is, 80–160 mgm. pregnanediol), this increase in pregnanediol output would necessarily have been observed. However, in the last two weeks of pregnancy no injected progesterone or only some few per cent were excreted (Table 1). It must therefore be concluded that a considerable decrease in recovery of injected progesterone occurs near term, apparently simultaneously with the increase in myometrial reactivity. This decrease in progesterone recovery may be due to: (1) a decrease in pregnanediol excretion and/or (2) a change in progesterone metabolism.

(1) A decrease in pregnanediol excretion would imply that the capacity of the kidneys to excrete pregnanediol is limited and that at term the upper limit is reached even before progesterone injection. If so, the excess of pregnanediol, produced by progesterone administration, must be excreted by some other route (the fæces ?). It is, however, difficult to understand why the upper limit should always be reached at the end of gestation, while it is never reached earlier in normal pregnancy, in both cases quite irrespective of the pre-injection level of urinary pregnanediol.

(2) A change in progesterone metabolism would mean that progesterone is transformed to metabolites other than pregnanediol. If so, the metabolic change may imply that neither endogenous nor exogenous progesterone ever reaches the myometrium as an effective substance. In this way the 'progesterone block'[5] is withdrawn as effectively as if the progesterone production had ceased. The difference between the rabbit and the human pregnancy, in respect of the endocrine control of the pregnant uterus, seems to be that in the rabbit only the amount of progesterone is of crucial importance, while in the human not only the amount but also the metabolism of progesterone are vital.

The relation between recovery of progesterone and myometrial reactivity, the nature of the decrease in recovery and the problem of other sources of urinary pregnanediol are now undergoing further investigation in our clinic.

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Discrepancy between the Distributions of Iodine in Human Serum when estimated by Iodine-131 and Iodine-127

In spite of indications to the contrary[1], it is generally assumed that only traces of iodotyrosines are normally present in circulating blood of human beings and animals[1,2]. This assumption is based on the distribution of the labelled iodoamino-acids observed after administration of iodine-131. Roche and Michel[1] state: "Thyroid hormone must be considered as being a mixture of L-thyroxine and L-3,5,3′-triiodothyronine and containing at least 90 per cent of the total plasma iodide". Previous work with stable iodine, however, suggests otherwise[3].

Recently, it has become feasible to determine the distributions of both the labelled[4] and the stable[5] serum iodine on the same chromatogram. Initial observations suggested a marked discrepancy between the distributions obtained by the two methods, as well as an unsuspectedly long equilibration period for iodine-131. These findings made in euthyroid individuals have been extended in a larger series, with essentially the same result.

Table 1. DISTRIBUTION OF IODINE-131 IN THE NON-PROTEIN FRACTION OF HUMAN SERUM

Patients*	Days after iodine-131	Percentage iodine-131 in DIT	MIT	I^-	T_4	T_3
Ha.	1	<1	<1	96	4	1
	3	<1	<1	51	42	7
	7	1	1	14	61	24
	10	4	3	15	28	50
	17	3	5	30	43	19
Ro.	1	<1	3	96	<1	<1
	5	<1	3	86	8	3
	7	3	1	50	37	9
	10	1	3	17	71	8
Ta.	3	<1	2	48	50	<1
Br.	33	1	1	16	55	27

DIT, Diiodotyrosine; MIT, monoiodotyrosine; T_4, thyroxine; T_3, triiodothyronine.
* Clinical status and sex of the patients in this table are listed in Table 2.

Table 2. DISTRIBUTION OF IODINE-127 IN THE NON-PROTEIN FRACTION OF HUMAN SERUM

Patient	Clinical status	Sex	No. of bloods tested	Percentage iodine-127 in DIT	MIT	I^-	T_4	T_3
Ha.	coronary	M	4	30±4	27±2	5±1	29±2	9±3
Ro.	coronary	M	4	29±4	19±3	5±1	35±4	12±4
Ta.	healthy	F	1	15	38	6	34	7
Br.	healthy	F	1	30	28	9	23	10
Wi.	healthy	M	1	29	8	<1	57	6
Le.	healthy	M	1	24	14	<1	58	4
Kl.	healthy	M	1	36	35	<1	28	2
Ch.	healthy	M	1	22	32	2	15	26
Me.	healthy	M	1	26	28	4	29	12
Ave.				27	25	4	35	10

DIT, Diiodotyrosine; MIT, monoiodotyrosine; T_4, thyroxine; T_3, triiodothyroxine.

Blood for iodine-127 chromatography was secured from seven healthy medical students and older volunteers. Blood was also drawn for iodine-131 and iodine-127 chromatography from two euthyroid patients, nearly recovered from a coronary occlusion, following administration of 150 and 200 μc. of iodine-131 respectively and from two individuals following the administration of 125 μc. of iodine-131.

The results are presented in Tables 1 and 2. As expected, the greatest part of the radioactivity was present in the serum as iodide 24–48 hr. after labelling. After this, the activity appeared mainly in the thyronine fraction, although a sizeable proportion was present as iodide in all specimens studied. Very little iodine-131 was found in the tyrosine fraction, even 10 days after labelling.

In contrast, the iodine-127 measurements show that approximately half the circulating iodine was in the form of diiodotyrosine and monoiodotyrosine, half as thyronines, but virtually no iodide. The identity of the monoiodotyrosine and diiodotyrosine has been confirmed by one- and two-dimensional co-chromatography in the presence of the radioactive compounds, and also by the ceric sulphate – methylene blue reaction[5] with and without added standards.

The distribution of the serum-iodinated compounds estimated from iodine-131 labelling conforms well with the reports in the literature[2]. It is demonstrated in the present study, however, that equilibrium is not necessarily attained by 72 hr., as has been generally believed[6]. Thus it is clear that the time after labelling with iodine-131 is an important factor in the result, which must be considered in any evaluation or comparison of chromatographic data based upon radioactivity. Conclusions from much of the work in the literature may need reappraisal on this account.

The finding in this study that about one-half of the iodinated compounds in human serum is present as iodotyrosines when stable iodine content is measured is thus most surprising. Since the determinations of both iodine-127 and iodine-131 were made on the same chromatogram, and since the behaviour of both labelled and stable standards processed in the same way matched the compounds in serum, on one- and two-dimensional chromatograms, it is unlikely that the findings are due to artefacts[3].

A reasonable explanation for the discrepancy may be found in the fact that varying dilutions of the isotope must take place within the thyroid. There is approximately ten times as much iodine in the iodotyrosines as in the iodothyronines[4]. If each group of compounds were to be secreted into the blood on a 1 : 1 basis, the specific activity in the iodotyrosines would be one-tenth that of the iodothyronines. With the usual labelling doses of iodine-131 currently employed, this low level of activity would be regarded as not significant.

The effect upon thyroid function of a coronary occlusion in the two patients followed serially several weeks before the study with iodine-131 might account for the slow rate of incorporation of the isotope into the thyronine fraction. However, the iodine-131 values in the specimens obtained at 72 hr. in two healthy volunteers and serially in a euthyroid healthy patient not presented here with non-toxic diffuse goitre and the conformity between the iodine-127 values of the patients and those of the healthy subjects, suggest that the thyroids were normally active and that slow labelling is a normal event.

Since chromatography with iodine-131 does not reveal the true distribution of the stable iodine, it seems possible that determination of both radioactive and stable iodine distributions may be necessary if greater insight is to be obtained into the disturbed mechanisms underlying certain unexplained disorders of the thyroid such as sporadic non-toxic goitre.

Following this work, Dr. James Wynn, Veterans Administration Hospital, Durham, N.C., has also found discrepancies between the iodine-127 and -131 results using quite different methods for separating the iodocompounds.

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BIOLOGY

Functional Changes in the Vacuole-containing Bodies of the Gastric Parietal Cell

The cytoplasmic inclusion known as the vacuole-containing body[1] was first found by Palade[2] in a study of the fine structure of the neurone and afterwards in tracheal, intestinal and renal tubular epithelia.

It consists of a cytoplasmic vacuole—0·2–1μ in diameter—bounded by a single membrane 60 A. thick, containing small circular vacuoles, 500 A. in diameter. No morphological changes have been hitherto described in vacuole-containing bodies and their function and nature are obscure.

Similar vacuole-containing bodies are found in the gastric parietal cells of the fasting mouse[3], where one or two are found in each section. They are smaller than the mitochondria, and consist of a vacuole—0·2–0·4μ in diameter—bounded by a single membrane, which contains a few small 500-A. vacuoles (Fig. 1*a*).

Following repeated injections of pilocarpine nitrate, certain changes occur within the parietal cell. The vacuole-containing bodies become more numerous—about 5–7 occur in each section—and are much larger, namely, 0·5–3μ diameter. The small contained vacuoles are unchanged in size, although their total number has increased (Fig. 1*b*).

Thus in the gastric parietal cell the vacuole-containing bodies undergo marked morphological changes according to the secretory state of the cell. Phase-contrast microscopy of 2-μ sections confirms that these vacuoles are visible in the active parietal cell, and thus it should be possible, with routine histochemical methods, to elucidate the nature of this structure.

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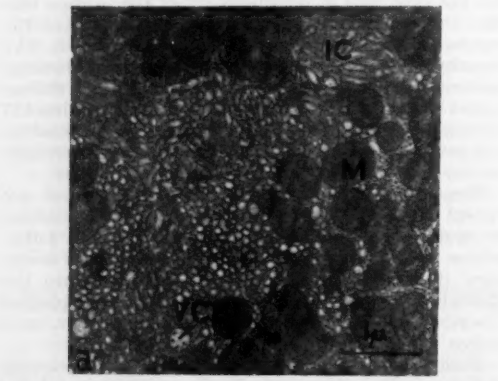

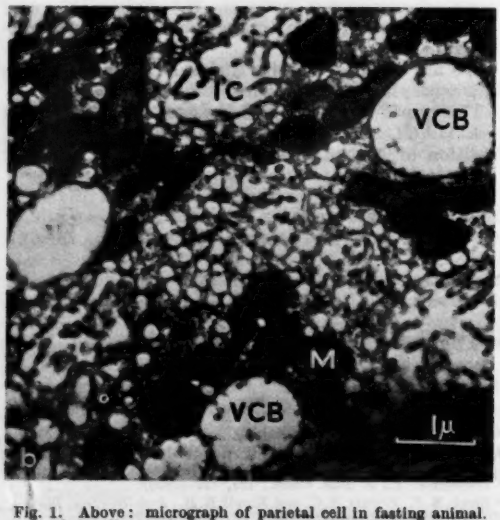

Fig. 1. Above: micrograph of parietal cell in fasting animal. A single small vacuole-containing body (*VCB*) is present. *IC*, intracellular canaliculus; *M*, mitochondria. (× 12,000). Below: micrograph of an actively secreting parietal cell. Several large vacuole-containing bodies (*VCB*) are visible. *IC*, intracellular canaliculus; *M*, mitochondria. (× 12,000)

Induction of Lung Tumours by Radioactive Particles

Inhalation provides one of the most accessible routes for the entry of radioactive materials into the body. To evaluate the health hazards of airborne radioactive particles, it is important to know the biological effects of their deposition in the respiratory tract. When relatively insoluble particles are involved, pulmonary tissues may receive a large radiation dose because of a low rate of clearance from the lungs. The occurrence of squamous cell carcinomas as a result of the intratracheal injection of $^{239}PuO_2$ was initially reported from this laboratory[1]. Recently, malignant tumours were described in rat lungs after intratracheal administration of $Ba^{35}SO_4$ and $^{144}CeF_3$ (ref. 2), polonium-210 (ref. 3), and after implantation of strontium-90 glass beads and cylinders plated[4] with ruthenium-106. This communication concerns the occurrence of malignant lung tumours in mice after intratracheal administration of $^{106}RuO_2$ as well as $^{239}PuO_2$.

Suspensions of $^{239}PuO_2$ and of $^{106}RuO_2$ particles suspended in either 0·1 per cent 'Tween-80' (Atlas Powder Co.) or 0·1 per cent 'Pluronics' (Wyandotte Chemical Corporation) were administered intratracheally to two-month-old female BAF_1 mice. Barium sulphate particles were also given to a group of mice as an example of a known innocuous particle[5,6]. Stable ruthenium dioxide was administered to an additional group of control animals. The relative insolubility of $^{106}RuO_2$ and $^{239}PuO_2$ was shown in other experiments[7,8]. Approximately 20 per cent of the original dose was present in lungs after 100 days and 5 per cent after 400 days. The mice were killed either 100 or 500 days after treatment and examined grossly and histologically for pathological changes.

Grossly, two types of lesions were distinguished: pulmonary papillary cystadenomas and pneumonitis. The tumours were pearly white and frequently located near the pleura. These tumours were easily identified unless obscured by pneumonitis. The pneumonitis was bacteriologically sterile, and the affected lungs were pale with focal necrosis.

Table 1. Incidence of Pathological Findings in Lungs after Intratracheal Injection of Particulates

Material injected	100 days			350 to 500 days				
	No. of mice	Percentage with papillary cystadenonas	Percentage mice with pneumonitis	No. of mice	Percentage with papillary cystadenomas	Days after administration	No. and type of malignant tumour	Calculated dose (rad)
None	50	14	0·0	28	78	403–470	0·0	—
0·1 ml. distilled water	25	16	0·0	15	66	430–479	0·0	—
0·1 mgm. 'Tween-80'	25	8	0·0	18	39	386–513	0·0	—
5 μgm. $BaSO_4$	55	16	5·0	4	100	405	0·0	—
0·01 mgm. 'cold' RuO_2	46	28	7·0	21	9	335–500	0·0	—
3 μc. $^{106}RuO_2$	41	56	42·0	23	82	350	1 undifferentiated	9,000
1·93 μc. $^{106}RuO_2$	—	—	—	11	90	369–422	1 alveolar cell	4,000
0·15 μc. $^{106}RuO_2$	—	—	—	10	—	340	1 lymphosarcoma	300
0·06 μc. $^{239}PuO_2$	25	20	72·0	17	51	400	2 squamous cell carcinoma	2,300
0·003 μc. $^{239}PuO_2$	30	30	—	21	30	500	1 fibrosarcoma	115

The results of gross and microscopic examinations are given in Table 1. No demonstrable increase in the incidence of papillary cystadenomas was observed in animals treated with radioactive particles. At 100 days pneumonitis was not seen in controls but occurred only after administration of particles. Pneumonitis was observed in about 5 per cent of animals administered barium sulphate or ruthenium dioxide. After administration of ruthenium-106 and plutonium-239 pneumonitis was observed in 42 and 72 per cent respectively of the animals.

A marked increase in histological effects was observed at 350–500 days relative to the earlier period in mice given radioactive particles. Sections of lungs from mice killed 100 days after administration of 0·06 μc. $^{239}PuO_2$ showed foci of proliferation of bronchiolar epithelium and squamous metaplasia. These lesions were within foci of fibrosis which surrounded deposits of radioactive particles. After 400 days many grossly affected lobes appeared atelectatic and fibrotic. Such lesions showed a progression of the fibrosis and epithelial hyperplasia with associated tumour development as described below. The lungs of mice given ruthenium-106 grossly appeared hyperæmic with discrete areas of fibrosis. Microscopically, epithelial proliferation was not apparent, but areas of necrosis and fibrosis were observed. The latter contained cells with large, bizarre, hyperchromatic nuclei. Several malignant tumours occurred in mice given radioactive particles. These were found after administration of $^{106}RuO_2$ and included an undifferentiated anaplastic tumour, an alveolar cell tumour, and a lymphosarcoma. Two squamous cell carcinomas and a mediastinal fibrosarcoma were observed in mice given $^{239}PuO_2$.

Estimates of the total dose to lung tissue for the mice showing malignant tumours are included in Table 1. The dose values were derived by assuming uniform distribution of the material in the lung and exponential loss with an effective half-life of about 30 days for $^{106}RuO_2$ and $^{239}PuO_2$ administered intratracheally. Since non-uniform distribution of the particles was evident from autoradiograms, microscopic volumes of tissue received doses larger than those estimated. The lymphosarcoma in the lung and the mediastinal fibrosarcoma had the lowest estimated radiation exposure of 115 and 300 rad. The genesis of these tumours had a less-certain relationship to the deposition of radioactive particles. The lungs involved showed no evidence of radiation tissue effects at autopsy, and the cell types may be considered atypical for radiation-induced tumours in this location. The other doses exceeded 2,000 rad and are in the range of estimated radiation doses which caused malignant pulmonary tumours in experiments summarized in the report of the Sub-Committee on Inhalation Hazards of the National Research Council[9].

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Sexual Maturity in *Drosophila*

D. J. Merrell[1] says in regard to the fertility of matings of *Drosophila* when employing males less than 24 hr. old and males aged for seven days: "The unaged flies were left together in the creamers for periods ranging from 18 to 72 hours; the aged flies were separated after 2 to 7 hours, the variation in time being due to differences in the length of time needed for fertilization to occur".

According to Bodenstein[2], formation of mature spermatozoa is initiated in the pupal stage around three days before emergence of the pupæ. But it is not until about 7 hr. after eclosion that the first motile sperms appear[3]. Thus a successful mating before this time is unlikely. However, observations of mating behaviour of young males indicate that they very infrequently mate before they are 12 hr. old.

It seems that young males, that is, 0–1 day old are more reluctant to mate than older males, that is, 3–4 days old. Thus, a personal communication from Lüning informs me that in tests he has made very small progenies are obtained from young males when the mating period is 60 min., compared with large progenies from older males. When the mating period is extended to 2–3 hr. even the young males have large progenies. Another observation by Lüning is that in the group with young males the first male copulated 30 min. after they were brought together with the females, while in the group with older males the first males had started mating already after 3 min.

That there are also strain differences in regard to rate of sexual maturity is indicated by the experiment described below.

Males 0–3 hr. old, but with fully stretched wings, were mated individually to single virgin hybrid females. When the males were 24 hr. old, they were given a new set of virgin females for another 24 hr. Then the males were discarded. The females were permitted to lay eggs for a 3-day period after the mating period. Later all vials were observed for hatched eggs. The experiment was carried out at a temperature of 25° C. Table 1 gives the results obtained for the two wild-type strains, Iso-Amherst and Oslo. These results indicate that there is a significant difference between these stocks regarding the frequency of successful cultures obtained from males 0–24 hr. old, but no significant difference when the males are 24–48 hr. old.

Table 1

Strains	First brood			Second brood		
	Total No. of cultures	No. of successful cultures	Successful cultures (per cent)	Total No. of cultures	No. of successful cultures	Successful cultures (per cent)
Iso-Amherst	117	42	35·9	112	98	87·5
Oslo	113	67	59·3	108	89	82·4

This would indicate that males from the Oslo strain reach sexual maturity at an earlier age than males from the Iso-Amherst strain.

For both strains there is a significant difference between successful cultures on the first and second day. This holds true for several wild-type strains tested.

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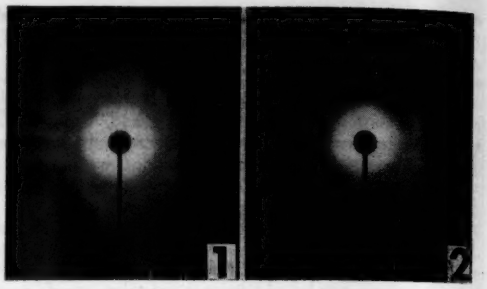
X-Ray Diffraction Patterns from the Egg Membrane of the Egg of the Brook Trout

Stimulated by the findings of Young and Inman[1] and Brown[2] that the capsule of salmonid eggs can be classified as a pseudokeratin, we have recently made X-ray studies of the egg membrane of the brook trout, *Salvelinus fontinalis*. The membrane from the fresh unfertilized egg was washed with Ringer's solution to remove traces of egg contents and dried at room temperature. For analysis a Laue-type diffraction camera was used, with a flat film cassette 4·8 cm. from the specimen. The diagram obtained with copper K_α radiation, either vertical or parallel to the surface of the dry specimen, was a continuous halo with two main peaks at about 4·5 A. and 13 A. respectively (Fig. 1). As is also seen in Fig. 1, there is a sharp ring surrounding the whole halo. However, examination reveals that this ring coincides with the strongest line of sodium chloride, 2·81 A., and is wholly lost from membranes which have been washed with fresh water prior to desiccation. Consequently, it may be assumed that this ring pattern is not characteristic of the egg membrane, but is merely caused by adherent crystals of sodium chloride from the washing medium.



Figs. 1 and 2. X-ray diffraction diagrams of the egg membrane (vertical to the membrane surface). 1, Egg membrane of intact, unfertilized egg; 2, membrane taken from activated egg

As has been pointed out by various workers, salmonid eggs have a weak and fragile capsule until shed, but become much tougher, so-called water-hardened, at the time of fertilization or artificial activation[3–7]. As to the mechanism of such membrane hardening, Hayes[3] has suggested that it is a "special case of the reorganization of a protein molecule to form a keratin-like substance". It is of interest to see whether this idea is confirmed by changes in X-ray diagrams. Therefore, the egg membrane taken from eggs undergoing activation in fresh water was subjected to X-ray analysis. Contrary to expectations, the diagram was of similar halo type, giving no evidence of keratin (Fig. 2); no significant difference was found between the two diagrams by the microphotometric examinations. The present X-ray studies thus afford no proof of the change in the molecular organization of the egg membrane supposed to occur at the time of laying.

We are grateful to Prof. K. Niwa, Hokkaido University, and to Dr. T. Katsufuji, for their valuable suggestions and criticisms during the course of the present work.

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Micro-Electrode Penetration of Ascites Tumour Cells

EHRLICH ascites tumour cells from mice were suspended in Krebs phosphate Ringer in agar and maintained at 37° C. in a small chamber. Ling–Gerard micro-pipettes were filled with 3 *M* potassium chloride. They had a tip resistance of 30–50 megohms, and were checked for tip potentials by Adrian's method[1]. Any showing tip potentials greater than 2 mV. were discarded. Penetrations were observed microscopically under a magnification of 600.

The input valve ('Hivac' *XE*2) and micro-pipette holder were carefully insulated from earth, the measured input resistance being greater than 10^{11} ohms. The grid current was less than 10^{-13} amp., the valve being biased above contact potential so that with the grid open, or the tip of the micro-pipette deliberately blocked by pushing it into the 'Vaseline' lining the bath, a negative potential resulted.

In general, a difference of potential of 5–10 mV., positive inside, appeared when the microtip just penetrated the cell wall. This difference of potential was stable and could be obtained repeatedly on successive impalements of the same cell. The microtip could be moved about inside the cell for a small distance without changing this difference of potential.

On pushing the microtip farther into the middle of the cell the difference of potential changed abruptly to a value of 20–40 mV., negative inside. This difference of potential remained constant for about 10 sec. and then declined slowly; small movements of the tip caused no further change. If the tip was withdrawn after one or two seconds, the sequence just described could be obtained several times in one cell.

Under favourable conditions the following sequence of events is observed. On bringing the microtip up to the cell a slight dimpling of the outer wall is seen. As penetration occurs this dimpling disappears and the cell seems to seal itself around the tip, as usually occurs with other types of tissue. At this stage a difference of potential of 5–10 mV. appears abruptly. As the tip is moved farther into the cell, an invagination appears in the interior granular material. This suddenly disappears and at the same time the potential difference changes abruptly to 20–40 mV., negative inside. In some cells the negative difference of potential appeared immediately on penetration. In others only the positive difference of potential was obtained, but in most of these the negative difference of potential appeared on a second penetration in a slightly different direction.

It would seem that the initial positive difference of potential exists between the cytoplasm and the external medium and that the negative difference of potential occurs on penetration of some internal structure of the cell.

Electron micrographs[2] show that the ascites tumour cell, the diameter of which is about 20–30μ, contains a very large nucleus, which may occupy up to half the volume of the cell and is often situated eccentrically; and that as the cells deteriorate they may develop vacuoles almost as large. However, with cells that were obviously deteriorating, the negative difference of potential was elicited much less frequently (although the positive could usually be obtained). Thus it is probable that the structure penetrated was the cell nucleus.

The positive internal potential of the cytoplasmic membrane could be explained, on the basis of the Goldman equation, if one assumes a high permeability to sodium compared with potassium[3]. It has been shown[4] that these cells have an abnormally high permeability to sodium.

I wish to thank Prof. F. H. Shaw for his encouragement and helpful advice during the course of this work.

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Differences between Self-Incompatibility and Self-Sterility

THE term 'self-sterile' is used for describing plants which fail to set self-seed when they are grown in isolation or when they are self-pollinated. Silow[1] reviewed the early usage of this term and proposed the term 'voluntarily self-sterile' to describe *Lotus* plants that fail to set seed when isolated from insects and 'artificially self-sterile' when they still fail to set self-seed following artificial self-pollination. He observed that several *Lotus* species in isolation set more self-seed following artificial self-pollination than the same plants without artificial self-pollination. This difference can be accounted for by the presence of a stigmatic membrane which prevents germination and growth of any pollen. This membrane is ruptured by artificial self-pollination or by insect pollination of the flower, after which pollen can germinate and grow. The presence of a stigmatic membrane was observed by Elliott[2] in *L. tenuis* and by Giles[3] in *L. corniculatus*. Giles[3] was unable to observe any difference in germination between self- and cross-pollen once the membrane ruptured. The presence of a similar membrane was observed by me[4] in several other *Lotus* species. This membrane can account for the observed voluntary self-sterility and for differences between voluntary and artificial self-sterility, but it does not account for artificial self-sterility.

Several mechanisms which can cause artificial self-sterility are known. One of these is genetic 'self-incompatibility', as was first described by East and Manglesdorf[5]. Another is 'somatoplastic sterility' which causes post-fertilization abortion, first described by Brink and Cooper[6]. Several other possible causes have been postulated. Mechanisms which involve post-fertilization abortion lead to destruction of individual ovules, whereas incompatibility saves the ovules for fertilization by any cross-pollen that may be present. Post-fertilization abortion may be suspected if all ovules do not form seeds following pollination by a mixture of cross- and self-pollen. However, variability in rate of ovule development within ovaries may be expressed in the same way, as discussed by me[4].

The terms 'self-incompatibility' and 'incompatibility' are used for describing certain genetic outbreeding mechanisms of a type first described by East and Manglesdorf[5]. Two main systems are found in angiosperms with homomorphic flowers. These systems are controlled by incompatibility alleles at one or two loci in which incompatibility is found

between the alleles in the pollen grain and the flower pollinated (gametophytic) or between the alleles of the pollen parent and the flower pollinated (sporophytic). The actual systems found are listed by Pandey[7]. These systems act on the incompatible pollen by retarding or inhibiting growth of pollen tubes. If a mechanism is provided to ensure that cross- and self-pollen germinate on the stigma at the same time, retarded growth alone will provide an effective incompatibility mechanism. This is a function of the stigmatic membrane in *Lotus*.

From these definitions, it can be seen that a self-sterile plant species may possess a genetic self-incompatibility mechanism; but it does not follow that the self-incompatibility mechanism is the direct cause of self-sterility. Also, a voluntarily self-sterile species which possesses an effective self-incompatibility mechanism may be either artificially self-sterile, artificially self-fertile or intermediate between these two possible extremes.

Our work with *Lotus corniculatus* indicates the importance of recognizing that incompatibility and self-sterility may be separate phenomena with independent genetic mechanisms. The presence of an incompatibility mechanism is indicated by differential growth-rates of pollen tubes within the ovaries with self- and cross-pollinations, as reported by Giles[3]. Also, the good fits to hypothetical genetic ratios obtained by Dawson[8] would be unlikely if an incompatibility system were not present, as he did not practise emasculation. The presence of self-sterility is indicated by reduced pod and seed set from flowers that are isolated from insects or from flowers that are self-pollinated, which has been demonstrated repeatedly as reported by Silow[1]. Giles'[3] observation that self-pollen tubes reach the base of the ovary beyond the basal ovules, although more slowly than cross-pollen tubes, and his further observation that the relative growth-rate of cross- and self-pollen tubes are the same in relatively self-fertile and self-sterile plants, are an indication that self-incompatibility is not the cause of self-sterility in *Lotus corniculatus*. Giles[3] and I[4] observed evidence of post-fertilization abortion following selfing and I also noted that some aborting ovules exhibited characteristics of 'somatoplastic sterility'. This may account for the observed self-sterility. Therefore, self-incompatibility and self-sterility should be considered as separate phenomena in this species.

It follows that self-sterility and self-incompatibility in *L. corniculatus* may be controlled by separate genetic mechanisms. Observations were made on pod and seed set from various reciprocal test crosses, including 64 test backcrosses between progeny and each parent, 56 test backcrosses between backcross progeny and the recurrent and cross parents, 157 S_1 progeny and their parents and 30 S_1 siblings were test crossed in all combinations. Although there was considerable variability in seed and pod sets, it was not possible to fit these data to any one-locus gametophytic incompatibility hypothesis, even if allowance is made for possible tetrasomic inheritance. Pandey[7] pointed out that certain incompatibility systems are characteristic of families and that this system is the one characteristic of Leguminosae. With further analysis, it was not possible to fit the data obtained to any of the other incompatibility systems that were listed by Pandey[7]. The results on setting of seeds and pods can be fitted to a polygenic inheritance model, as would be expected if self-sterility is caused by loss of heterosis leading to somatoplastic sterility. It appears that the results obtained measure self-sterility and that no evidence on the genetics of self-incompatibility has been obtained. It is highly probable that independent genetic mechanisms control self-incompatibility and self-sterility in this species.

The concept that incompatibility that does not produce self-sterility may be effective in outbreeding was developed by Bateman[9]. In *Lotus corniculatus*, it should be possible to breed out self-sterility without weakening the self-incompatibility system. Then, if suitable inbred lines can be produced, it should be possible to produce hybrid seed commercially in isolated fields using insect pollinators. We would expect a high proportion of hybrid seed from every flower that is visited by an insect carrying a mixture of pollen. Bees could also be used for producing self-seed in other isolated fields since incompatibility does not cause self-sterility. Fields used for hybrid seed production could be seeded in alternate rows or with mixtures of self-seed. Since evidence of hybrid vigour in *L. corniculatus* has been obtained by Mr. N. C. Lawson at Macdonald College (unpublished work), this offers a promising approach to breeding this species. It would appear that a similar approach would be very promising in other legumes where it may be possible to separate self-incompatibility and self-sterility. For example, the breeding plan for *Medicago sativa* presented by Bolton[10] may be more practical if these considerations are applied in this instance.

These results will be published in detail elsewhere.

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A Technique for the Sterile Culture of Roots

The experimental methods which have been employed for studies of metallic ion deficiency effects in plant and animal chromosomes have hitherto involved the entire organism[1,2], and consequently have been under conditions of only partial control. It seemed desirable to design a method by which control of cell nutrition could be more closely approached. The method was developed for use in investigations of the effects of metallic ion deficiencies or excesses on chromosome structure, but it is not limited to experiments of this type. The technique has a two-fold advantage. In addition to maintaining control of nutrition, it is possible to use clonal lines of tissue for cytological studies, since many lateral roots can be obtained from a single bean of *Vicia faba*, and these roots can be maintained in culture. Brown and Possingham[3] have used a root-culture technique for

Table 1

Compound	gm./l.	Percentage in solution	Stock solution (per cent)	Dilution for final solution (c.c.)
Glucose	20	2	none	none
$Ca(NO_3)_2.4H_2O$	0·236	0·0236	2·36	10/1,000
$MgSO_4.7H_2O$	0·036	0·0036	3·60	1/1,000
KNO_3	0·081	0·0081	0·81	10/1,000
NaCl or KCl	0·065	0·0065	0·65	10/1,000
KH_2PO_4	0·012	0·0012	0·12	10/1,000
$Fe_2(SO_4)_3$	0·002	0·0002	2·00	0·1/1,000
Trace elements	(mgm./l.)			
H_3BO_3	0·06	0·000006	0·06	0·1/1,000
$CuSO_4.5H_2O$	0·04	0·000004	0·04	0·1/1,000
$MnSO_4.4H_2O$	0·04	0·000004	0·04	0·1/1,000
$ZnSO_4.7H_2O$	0·04	0·000004	0·04	0·1/1,000
$NaMoO_4.2H_2O$	0·02	0·000002	0·02	0·1/1,000
$FeCl_3.6H_2O$	2·00	0·0002	0·20	1/1,000
Gibberellic acid	5·00	0·0005	0·50	1/1,000

Table 2

Vitamin	mgm./100 c.c.
Biotin	10
Choline chloride	10
Folic acid	10
Nicotinamide	10
Calcium pantothenate	10
Pyridoxal hydrochloride	10
Thiamine	10
Riboflavin	1
B_{12}	10

100 c.c. stock solution made alkaline with 1 *N* sodium hydroxide until vitamins completely dissolved. Dilute as 10 c.c. (stock solution) in 1,000 c.c. medium

investigations of the effect of iron in *Pisum*, but their method differs somewhat from that described here because of a difference in the handling of the organisms, and the purposes for which the roots were cultured were not entirely the same.

The medium used is a modification of that developed by Bonner and Addicott[4]. The trace elements in the medium follow those used by Brown and Possingham. Each component of the medium is made up as a concentrated stock solution (Table 1) which can be kept refrigerated or frozen, and is diluted into the final volume of medium each time fresh medium is prepared. The vitamin solution (Table 2) is prepared by filter-sterilization and kept frozen in small aliquots which are added to the medium after the latter has been autoclaved. The medium is placed in milk dilution bottles which can be fitted with a Cornwall syringe apparatus, and the bottles are sterilized at 20 lb. pressure at 121° F. for 20 min. Following sterilization, the medium can be stored under refrigeration until needed, at which time the sterile vitamin solution is added.

Seeds (*Vicia faba*; variety Seville Longpod: Carters Tested Seeds, Ltd., London) were chosen for their high percentage of germination and low frequency of spontaneous chromosomal aberrations. The seeds are sterilized by immersion for 30 min. in a saturated solution of calcium hypochlorite in which 3 gm. of wetting agent (for example, 'Dreft') per litre have been dissolved. Storage dishes containing pure silica sand (coarse grade, American graded sand) and distilled water are autoclaved. The beans are then partially embedded in the sand. 'Vermiculite' should be used in place of the sand if the beans are not to be grown deficient in metallic ions. The beans are allowed to grow at 20–25° C. for 7–10 days. The sand is kept very moist, but with little or no excess water. When lateral roots appear to be at least 2 cm. in length they are ready for excision and transfer to culture plates. The lateral roots can usually be seen along the bottom and sides of the storage dishes. *Allium cepa* seeds, variety Southport White Globe, Associated Seed Growers, New Haven, Conn., were also used. These are sterilized as described for *Vicia faba* and placed in sterile Petri plates on moist filter paper. The roots are ready for excision and transfer to culture plates after about 4–5 days, when they are 2–4 cm. in length.

A thin layer of 'Pyrex' glass wool is placed in a 5-cm. Petri dish and the plates are autoclaved. Filter paper or fine graded, pure silica sand can be used in place of the glass wool if deficiencies are not required. Sterile medium is dispensed into the Petri dishes by a Cornwall syringe in amounts of 2–2·5 ml./plate. The medium used at the beginning of culturing contains gibberellic acid. The amount of medium used is enough to wet the glass wool, sand, or filter paper thoroughly. Tips of the lateral roots of *Vicia faba* or primary roots of *Allium cepa* are cut to a length of 0·5–1·0 cm., and 4–5 tips are placed in each Petri dish. The roots are incubated at 20–25° C., and are kept moist, but not covered with the medium, as required during growth. Two days following root excision they are transferred to fresh medium in fresh dishes, the medium now lacking gibberellic acid. The latter is done since gibberellic acid tends to slow down growth following the initial elongation of the roots. The roots are kept moist as described, and transferred every 4–5 days to fresh medium. The standard Feulgen method is used for preparation of root tip smears.

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Response of Rice to Small Differences in Length of Day

The natural annual variation in length of day in Malaya is from 41 min. in the north (lat. 6° N.) to 8 min. in the south (Singapore; lat. 1° 20′ N.). The monthly differences in length of day in the principal rice-growing areas lie between 1 and 3 min. It has been recognized in reports of rice sowing date experiments in Ceylon[1,2] in Indonesia[3] and in Japan[4], that observed differences in time of emergence and maturation of the ear are possibly due to these small monthly differences in length of day. It has also been suggested that a decreasing length of day will advance flowering while an increasing length of day will delay flowering of rice[3,5].

Monthly sowings of a Malayan rice, Siam 29—an *indica* variety of rice (*Oryza sativa*, L.), were carried out at Malacca (lat. 2° 12′ N.) and Kota Bahru (lat. 6° 09′ N.) and the results (Table 1) show considerable variation in the times to emergence of the ear for each sowing date.

These results, which are typical of a number of experiments carried out in Malaya[5,6] show that plants sown in north Malaya flower earlier than those sown in the south for any given sowing date. The differ-

Table 1. Time to Ear Emergence at Different Latitudes in Days

Place	Day-length				Month of sowing (all sowings on 1st of month)											
	Maximum*		Minimum*		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	hr.	min.	hr.	min.												
Malacca	12	14	12	00	329	311	—	232	214	199	187	168	161	172	—	205
Kota Bahru	12	28	11	47	266	276	272	217	202·5	174·5	153	141	128	127·5	135	138

* Maximum and minimum lengths of day occur during the summer and winter solstice respectively.

ences are almost certainly not due to responses to temperature for there is very little change in temperature with latitude or season in Malaya[5]. Since the rice variety used in these experiments does not become sensitive to length of day until it is 4 weeks old, the lengths of day effective for inducing flowering must occur some 4 weeks after planting. The number of inductive short days which can be utilized by the plant in the north are more than in the south. They are also shorter. As short-day plants react to the dark period rather than to the light period, dark induction of flowering takes place in a shorter time in north than in south Malaya. Such sowing date experiments therefore indicate the photo-inductive effect of length of day to be cumulative, and suggest that the daily changes which occur with increasing length of day do not delay flowering and that the daily changes with decreasing length of day do not advance flowering.

To test this hypothesis, duplicate plants of Siam 29 were sown in pots in Kuala Lumpur (lat. 3° 08′ N.) and given continuous treatment with lengths of day differing by 5 or 10 min. The required lengths of day of 11 hr. 40 min.; 11 hr. 50 min.; 11 hr. 55 min.; 12 hr.; 12 hr. 5 min.; 12 hr. 10 min.; and 12 hr. 20 min. were obtained by covering each individual plant with an opaque cylindrical cover. All covers were removed manually as rapidly as possible each morning, and were replaced at the required intervals each evening. All covers could be removed within 4 min. Thus the day-length error in any one treatment was in the region of 15–20 sec.

The results, which record the mean time to 50 per cent ear emergence and to harvest for the duplicates, are shown in Fig. 1. In spite of the technical difficulties involved, the curves obtained are reasonably smooth. The results for 11 hr. 30 min. length of day has been taken from another experiment[6] carried out on the same variety. These results show that the response of Siam 29 is directly related to the length of day. The longer the total amount of darkness (that is, the shorter the day) received during the period of sensitivity the more rapidly does the ear emerge.

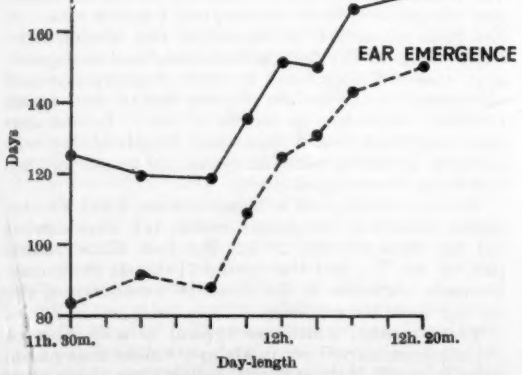

Fig. 1. Time to flowering and harvest in Siam 29

Chandraratna has produced curves of photosensitivity of a number of *indica* rice varieties, and these show that there are a minimum and a maximum length of day for effective flower stimulation. Rice is thus shown to be a short-day plant with a qualitative day-length response, which possesses no strongly defined critical day-length. Lang[8] has noted that plants with this type of behaviour cannot be fitted into the normal definitions of long- and short-day plants. Neither can their photosensitive behaviour be fully explained on the basis of the phasic and hormone theories of Gregory[9]; Hamner[10] and Lang[8]. The presence in such varieties of two limiting dark periods suggests that an internal mechanism of the diurnal type described by Bunning[11] provides a more satisfactory explanation for the behaviour of the plant to photoperiods of the order of 12 hr. If it is assumed that Siam 29 behaves in the same way as the varieties studied by Chandraratna[7] its response to very small differences is explainable, since the natural lengths of day found in Malaya and the lengths of day used in the experiment described here will fall in the steepest part of the photosensitivity curve characteristic of *indica* varieties of rice. Such lengths of day will also be of the same length as one of Bunning's[11] diurnal periods and will thus show the maximum inhibition of flowering, whereas plants receiving day-lengths less than 12 hr. will flower earlier because of the greater effectiveness of the light received during the middle of one of these periods.

It is hoped that further investigations of this phenomena will be made using a specially designed time-switch which can accurately control lengths of day to 1-min. intervals, and which is now available in this department.

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A Method of growing Grass Plants with Separation of Seminal and Adventitious Roots

In the course of physiological investigations on grass roots it was necessary to grow plants of timothy (*Phleum pratense* L.) with their seminal and adventitious root systems separate from each other, so that different nutrients could be fed to each.

Although 'split root' techniques have been used in the past[1], no satisfactory method has been described. Timothy seedlings have a single, very thin seminal root easily killed by desiccation. Solutions can be supplied separately to seminal and adventitious roots, but tend to intermix as a result of capillarity or surface-tension effects. The following simple method of preventing this intermixture has been found to work well: plants have been grown to the flowering stage by this means.

Seeds are germinated on gauze ('Terylene' net, supported by a ring floating on dilute culture solution, has been found to be satisfactory). When the seminal root is 10–15 mm. long, but before adventitious roots appear, seedlings are transferred to containers constructed as shown, in vertical section, in Fig. 1. The pots are polystyrene containers now widely used for packing jam and other foods, and are obtainable in several colours or transparent and colourless. A glass tube is sealed by heat into a hole in the base of the inner pot, and passes through a larger hole in the base of the outer pot. Both pots contain dry 'Vermiculite', retained at the holes by glass wool. The polythene top of the inner pot has a short (3–4 cm.), fairly wide (4–5 mm.) glass tube sealed through it, and a small hole in the centre through which the seminal root of the seedling is threaded and afterwards sealed in, from the inside, with wax of low melting point (39° C.). This top, complete with seedling, is then fitted on the pot, and more 'Vermiculite' is added to the outer pot, covering the top of the inner one as deeply as possible without burying the seedling. The 'Vermiculite' is then soaked with water or culture solution, the glass tube in the lid of the inner pot being used for watering this pot. The lower tube prevents mixing of the drainage from the two pots: its end should be treated with wax or a silicone preparation to prevent liquid from creeping up it, or, alternatively, a length of flexible tubing may be attached to lead away the drainage.

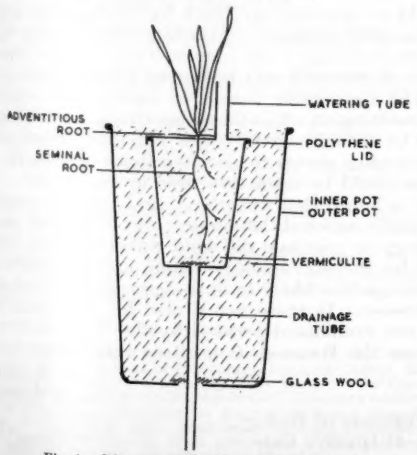

Fig. 1. Diagram of double-pot arrangement

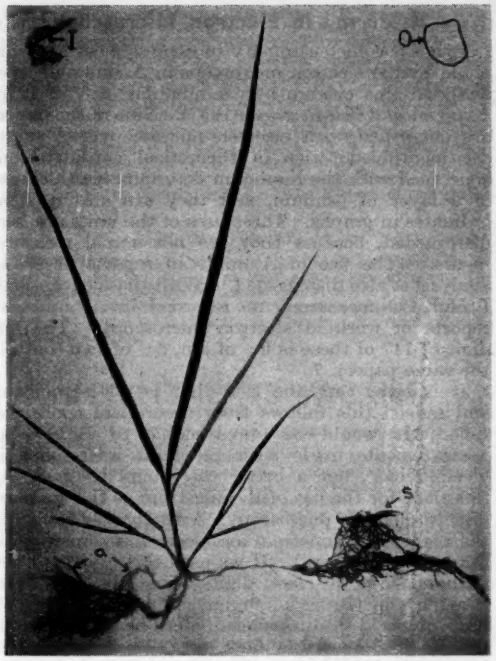

Fig. 2. Autoradiograph of a 5-week-old timothy plant. 5 μc. of sulphur-35 was given to the inner pot, and the plant was killed and exposed to X-ray film four days later. Film exposed for eight days. *s*, Seminal roots; *a*, adventitious roots; *I*, image given by 'Vermiculite' from the inner pot; *O*, position of 'Vermiculite' from outer pot

The pots used have capacities of 40–335 ml. However, a 335-ml. pot could conveniently be used as the inner one, with an ordinary plant pot as the outer; this would enable plants to be grown to a larger size before becoming 'pot-bound'.

A test was made to ensure that no transfer of solution took place between the two pots. 2 or 5 ml. of solution containing cæsium-137 were added to the inner or outer pots, respectively, of six containers in which there were growing seedlings. After a week, during which only enough culture solution was added each day to keep the 'Vermiculite' saturated, counts were made, with a scintillation counter and a rate-meter, of 'Vermiculite' from the untreated section of each container. The counts ranged from 2·9 to 3·3 per sec. (background count, 2·9) while a similar sample from a treated section gave a count of 60 per sec.

Experiments have since been carried out using sulphur-35 as a tracer. Autoradiographs were prepared of the 'Vermiculite' as well as of the plants. While in most cases the tracer has been found in both root systems, no matter to which it was directly supplied, 'Vermiculite' from the untreated pots has never given a positive autoradiograph, while that from treated pots has given a very clear image (Fig. 2). From this it is concluded that the sulphur-35 was translocated to the untreated root system through aerial parts of the plant, in which it was invariably found.

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A. or mμ in Electron Microscopy?

It has become customary to express measurements made by the electron microscope in A. units. I have analysed this custom by examination of Vol. 12 of *Experimental Cell Research* (1957). Nine of the papers are concerned with electron microscopy. A. units are mentioned twice in theoretical considerations concerned with the minimum determinable thickness of a layer of osmium, and they are also used as ordinates in graphs. These uses of the units are here disregarded, because they are not actual measurements. (The use of A. units in reports of X-ray analysis is also disregarded.) With these exceptions, I find 129 measurements recorded in A. units in reports of work in electron microscopy. The last digit of 117 of these is 0; of ten, 5; of two (both in the same paper), 7.

It is clear that the last digit is not significant, and indeed this follows from theoretical considerations. It would be unreasonable to express all measurements made with the light microscope in 'decimicrons', but a better case could be made for this than for the use of the angstrom as the standard unit in electron microscopy. Actually, we have just the right denomination for electron microscopy in the millimicron (mμ). If we used this unit (as a few authors do), the last digit would be significant (though the tissues of organisms would necessarily have changed in dimensions before being measured).

It is a remarkable fact, not recognized by the inventors of the metric system, that the human mind jumps naturally in thousands. Thus we write 2,654,396, not 2,65,43,96 or 265,4396. Similarly, no denominations between millimetre and micron have been found necessary. The decimetre is seldom used, and the centimetre only gained popularity because it was arbitrarily chosen as the unit of length in the C.G.S. system. The really useful measurements of length are the kilometre, metre, millimetre, and micron; and the millimicron is the logical continuation of the series.

John R. Baker

Department of Zoology,
University Museum,
Oxford.
Dec. 8.

Reorganization of Microbiological Research in Britain

I write to report the views of the Council of the Institute of Biology on the leading article in *Nature* of January 3 which dealt with the reorganization of industrial microbiological research in Britain. The article was informative but did not, it is felt, bring out the fundamental points at issue.

The proposals to strengthen microbiology in the stations of the Department of Scientific and Industrial Research concerned with particular technologies and to support fundamental microbiological research within university departments are in themselves admirable. But the most urgent need in industrial microbiological research is for work that bridges the gap between fundamental university research and its applications in diverse technologies. Such work, basic research undertaken with the needs of technology in mind, is carried out in other fields by the National Physical and National Chemical Laboratories within the Department of Scientific and Industrial Research and elsewhere by the stations and university research units controlled by the Medical and Agricultural Research Councils. The Microbiology Group at Teddington was the only group in Britain doing work of this character in industrial microbiology.

The Research Council of the Department of Scientific and Industrial Research has now abandoned responsibility for microbiological research of this character, despite the acknowledged success of the Teddington unit. Its decisions make no provision for a research unit on general industrial microbiology within the Department of Scientific and Industrial Research. It should be clearly understood that university units similar to the Medical or Agricultural Research Council's research units at universities are *not* contemplated and that the research grants to be made available to university departments will be of the same character as existed before these decisions were made.

All parties that have made representations against these decisions, including the late Advisory Committee on Microbiology, the Institution of Professional Civil Servants and ourselves, have emphasized that the research needed in this field is of a long-term character; sometimes, as with the methane-producing bacteria, very long term. It requires a research centre—a government laboratory or university unit of some size—which will provide a career for mature scientists experienced in the needs of technology as well as pure microbiology. Short-term grants to support postgraduate students on isolated projects in university departments will be totally inadequate, though they would be a valuable supplement to work of such a research centre.

What, in fact, will happen if the decisions of the Research Council of the Department of Scientific and Industrial Research are carried out? The present research group at Teddington—small but important because of its collective strength—will disappear, and in our view little if any of its work will be continued elsewhere in Great Britain. The real value of its work has been appreciated by British industry and by microbiologists all over the world. The National Collection of Industrial Bacteria, a world-famous collection of high repute, will be removed to the Torry Research Station in Aberdeen, which houses a collection of marine bacteria excellent in itself but comparable neither in scope, reputation nor size. The Research Council will have antagonized the whole world of microbiology, both by its decisions and by its cavalier treatment of the late Advisory Committee on Microbiology; one may well ask how the Department of Scientific and Industrial Research can expect in the foreseeable future to recruit any reputable microbiologists. The Corrosion Group at Teddington will be strengthened; a few university departments will receive grants for isolated items of research, but these could be made available in any event.

It is hoped that something can be done to establish a small national laboratory for industrial microbiology to continue the work which has been carried out by the Microbiology Group and to initiate new investigations likely to have significance for industrial processes. Is there not a case for an expert committee, nominated perhaps by the Royal Society, to advise the Research Council on this matter?

D. J. B. Copp
(General Secretary)

Institute of Biology,
41 Queen's Gate,
London, S.W.7.

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, February 9

UNIVERSITY COLLEGE, DEPARTMENT OF BIOCHEMISTRY (in the Physiology Theatre, Gower Street, London, W.C.1), at 5 p.m.—Prof. A. Haddow, F.R.S.: "The Chemistry and Biology of Cancer".* (Further lectures on February 16 and 23.)

BRITISH SOCIETY FOR THE PHILOSOPHY OF SCIENCE (previously PHILOSOPHY OF SCIENCE GROUP) (in the Joint Staff Common Room, University College, Gower Street, London, W.C.1), at 5.30 p.m.—Prof. P. G. Espinasse: "The Concept of the Gene".

INSTITUTION OF ELECTRICAL ENGINEERS (at Savoy Place, London, W.C.2), at 5.30 p.m.—Discussion on "Dissemination and Assimilation of Technical Literature" opened by Mr. J. K. Webb.

UNIVERSITY OF LONDON (at King's College, Strand, London, W.C.2), at 5.30 p.m.—Dr. P. Ledoux (Université de Liège): "The Present State of the Stellar Stability Problem".*

ROYAL AERONAUTICAL SOCIETY (at the Institution of Civil Engineers, Great George Street, London, S.W.1), at 6 p.m.—Mr. E. G. C. Burt: "Theoretical Studies of Guided Missile Control Systems".

Tuesday, February 10

UNIVERSITY COLLEGE (in the Anatomy Theatre, Gower Street, London, W.C.1), at 1.15 p.m.—Mr. F. Parkinson: "Social Problems of Underdeveloped Countries".

ROYAL SOCIETY OF ARTS, COMMONWEALTH SECTION (at John Adam Street, Adelphi, London, W.C.2), at 5.15 p.m.—Dr. T. F. West: "The History of the African Pyrethrum Industry".

UNIVERSITY OF LONDON (at King's College, Strand, London, W.C.2), at 5.30 p.m.—Dr. P. Ledoux (Université de Liège): "The Secular Stability of Stars and Stellar Evolution".*

SOCIETY OF CHEMICAL INDUSTRY, CHEMICAL ENGINEERING GROUP (at 14 Belgrave Square, London, S.W.1), at 6 p.m.—Mr. W. D. Jamrack, Mr. R. A. Wells and Dr. J. H. Buddery: "The Extraction of Thorium".

ROYAL INSTITUTE OF CHEMISTRY, LONDON SECTION (joint meeting with the SIR JOHN CASS COLLEGE CHEMICAL SOCIETY, at the Sir John Cass College, Jewry Street, London, E.C.3), at 6.30 p.m.—Dr. E. Lester Smith, F.R.S.: "Vitamin B_{12}—Recent Advances".

Wednesday, February 11

PHYSICAL SOCIETY, LOW TEMPERATURE GROUP (at the Royal School of Mines, London, S.W.7), at 4 p.m.—Dr. T. J. Webber: "Some Problems in the Handling and Distribution of Liquefied Gases".

GEOLOGICAL SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Dr. J. E. Prentice: "The Lower Culm Measures of the District South-West of Barnstaple, North Devon".

UNIVERSITY COLLEGE (in the Anatomy Theatre, Gower Street, London, W.C.1), at 5.30 p.m.—Prof. H. Behnke (University of Münster): "Modern Theory of Complex Functions of Several Variables. 1: The Notion of Complex Space".* (First of three Special University Lectures in Mathematics. Further lectures on February 12 and 13.)

COLLEGE OF PRECEPTORS (in association with the School Nature Study Union, at 2 and 3 Bloomsbury Square, London, W.C.1), at 6 p.m.—Miss M. Hollings: "Should a Teacher of Natural History be Bound by a Syllabus ?"

SOCIETY OF INSTRUMENT TECHNOLOGY, DATA PROCESSING SECTION (at Manson House, Portland Place, London, W.1) at 6 p.m.—Mr. L. Airey: "A Digital Instrumentation System for Use in the Testing of Jet Engines".

SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP (at 14 Belgrave Square, London, S.W.1), at 6.30 p.m.—Mr. S. C. Britton and Mr. K. Bright: "Recent Research on the Corrosion of Tinplate".

Thursday, February 12

INSTITUTION OF CHEMICAL ENGINEERS (at Church House, Westminster, London, S.W.1), at 9.30 a.m.—Symposium on "Mass Transfer".

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Prof. A. Haddow, F.R.S.: "The Chester Beatty Research Institute".

LINNEAN SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Dr. J. L. Monteith: "Micro-meteorology in Relation to Plant and Animal Life".

ROYAL INSTITUTION, LIBRARY CIRCLE (at 21 Albemarle Street, London, W.1), at 5.30 p.m.—Mr. James Lawrie: "Reading about Science".

ROYAL AERONAUTICAL SOCIETY (at the Institution of Mechanical Engineers, Birdcage Walk, Westminster, London, S.W.1), at 6 p.m.—Mr. W. H. Stephens: "Earth Satellites".

CHEMICAL SOCIETY (in the Large Chemistry Lecture Theatre, Imperial College of Science and Technology, South Kensington, London, S.W.7), at 7.30 p.m.—Prof. E. R. H. Jones, F.R.S.: "Polyacetylenes" (Pedler Lecture).

Friday, February 13

BRITISH PSYCHOLOGICAL SOCIETY, OCCUPATIONAL PSYCHOLOGY SECTION (in the Department of Psychology, Birkbeck College, Malet Street, London, W.C.1), at 1 p.m.—Dr. J. B. Parry: "The Place of Personality Appraisal in Occupational Selection" (Chairman's Address).

ROYAL ASTRONOMICAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Anniversary Meeting (followed by Annual General Meeting).—Dr. W. H. Steavenson: "The Instruments of Sir William Herschel" (Presidential Address).

INSTITUTION OF MECHANICAL ENGINEERS (at 1 Birdcage Walk, Westminster, London, S.W.1), at 6 p.m.—Prof. F. K. Bannister: "Induction Ramming of Small High Speed Air Compressor".

BRITISH INSTITUTION OF RADIO ENGINEERS, MEDICAL ELECTRONICS GROUP (at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1), at 6.30 p.m.—Mr. Peter Styles: "Some Instrumentation Problems in Medical Electronics with particular reference to Electromyography".

ANTIQUARIAN HOROLOGICAL SOCIETY (at the Science Museum, South Kensington, London, S.W.7), at 7 p.m.—Mr. F. H. Knowles Brown: Illustrated lecture on "The A. H. S. Tour in Switzerland, June 1957".

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 9 p.m.—Dr. Harry Godwin, F.R.S.: "The History of the British Flora".

Saturday, February 14

BIOCHEMICAL SOCIETY (in the Beveridge Hall of the Senate House, University of London, W.C.1), at 10.30 a.m.—Symposium on "The Biosynthesis and Secretion of Adrenocortical Steroids".

LONDON COUNTY COUNCIL (at the Horniman Museum, London Road, Forest Hill, London, S.E.23), at 3.30 p.m.—Mr. Norman Cook: "Unearthing London".*

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

ASSISTANT INSPECTORS OF FISHERIES (5) (with a degree or equivalent in zoology, plus an adequate knowledge of botany) IN THE DEPARTMENT OF LANDS, Dublin—The Secretary, Civil Service Commission, 45 Upper O'Connell Street, Dublin, Ireland (February 13).

TECHNICIAN (with workshop and preferably previous hospital experience) IN THE PHYSICS DEPARTMENT—The Administrative Officer, Marie Curie Hospital, 66 Fitzjohn's Avenue, London, N.W.3 (February 13).

BIOMETRICIAN IN THE DEPARTMENT OF RESEARCH AND SPECIALIST SERVICES—Ministry of Agriculture, Federation of Rhodesia and Nyasaland, for duties which will include the design of experiments in all phases of agriculture and animal husbandry research, together with the analysis of data and related statistical practice—The Secretary (R), Rhodesia House, 429 Strand, London, W.C.2 (February 14).

LECTURER OR ASSISTANT LECTURER IN MECHANICAL ENGINEERING—The Registrar, Manchester College of Science and Technology, Manchester 1 (February 14).

ASSISTANT LECTURER (qualified in either pure or applied mathematics) IN MATHEMATICS—The Registrar, University College of North Staffordshire, Keele, Staffs (February 16).

SENIOR LECTURER (suitably qualified man or woman) IN RADIOCHEMISTRY at the College of Technology, Liverpool—The Director of Education, 14 Sir Thomas Street, Liverpool 1 (February 20).

LEVERHULME RESEARCH FELLOWS (2) IN RADIOASTRONOMY—The Registrar, The University, Manchester 13 (February 21).

ASSISTANT LECTURER (veterinary surgeon or with a degree in physiology) IN THE DEPARTMENT OF PHYSIOLOGY—The Secretary, Royal Veterinary College (University of London), Royal College Street, London, N.W.1 (February 28).

ASSISTANT (science graduate, preferably with qualifications in physiology) IN CLINICAL CHEMISTRY—The Secretary, The University, Aberdeen (February 28).

FELLOW (preferably with a Ph.D. degree in physics or metallurgy or equivalent research experience in these fields) IN METAL PHYSICS, Division of Tribophysics, C.S.I.R.O., Melbourne, Australia, to study crystal defects and the mechanism of plastic deformation—Chief Scientific Liaison Officer, Australian Scientific Liaison Office, Africa House, Kingsway, London, W.C.2, quoting Appointment No. 370/123 (February 28).

LECTURER IN THE DEPARTMENT OF ASTRONOMY—The Secretary, The University, Edinburgh (February 28).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOWS IN CHEMISTRY, BIOCHEMISTRY, PHYSICS, ENGINEERING, CHEMOTHERAPY and related subjects—The Secretary, Academic Council, The Queen's University, Belfast (March 1).

PRINCIPAL—The Secretary, The Royal College of Science and Technology, George Street, Glasgow, C.1 (March 1).

BOTANICAL ARTIST (RESEARCH ASSISTANT II) (with a knowledge of plant form equivalent to that required at G.C.E. (Advanced Level) and preferably art training to the level of National Diploma in Design), to make plant models and illustrations—The Secretary, National Museum of Wales, Cardiff (March 6).

RESEARCH FELLOW OR FELLOW IN THE DEPARTMENT OF STATISTICS, Research School of Social Sciences, Australian National University, Canberra, for work in the field of mathematical statistics and its applications to other sciences—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Australia, March 16).

PRINCIPAL (with high academic qualifications and appropriate educational and administrative experience)—Clerk to the Governing Body, Northern Polytechnic, London, N.7 (March 31).

ASSISTANT OR ASSOCIATE PROFESSOR (with an honours degree in mathematics and preferably some postgraduate experience in research or teaching) IN THE DEPARTMENT OF MATHEMATICS—Head of the Department of Mathematics, University of New Brunswick, Fredericton, N.B., Canada.

ASSISTANT STATISTICIAN (with an honours degree in statistics, or in mathematics with a diploma in statistics, and desirous of working in the fields of biology or medicine) IN THE MEDICAL RESEARCH COUNCIL'S PNEUMOCONIOSIS RESEARCH UNIT, Cardiff—The Director, Pneumoconiosis Research Unit, Llandough Hospital, near Penarth, Glamorgan.

ASSISTANT PROFESSOR OF CHEMISTRY, to teach physical chemistry up to honours degree standard—The President, Memorial University of Newfoundland, St. John's, Newfoundland, Canada.

FREELAND CHAIR OF CHEMISTRY—The Secretary, The Royal College of Science and Technology, Glasgow.

GEOLOGIST (with an honours degree in geology or equivalent qualification, special qualifications in ore mineralogy, and postgraduate experience in handling problems of ore genesis and ore microscopy), for duties chiefly concerned with laboratory work in Copenhagen, and also a certain amount of field work in Greenland—The Director of Survey, Grønlands Geologiske Undersøgelse, Østervoldgade 7, Copenhagen K., Denmark.

HEAD OF THE DEPARTMENT OF PHYSICS—Chairman of the Staff Committee, Essex College, Assumption University of Windsor, Windsor, Ontario, Canada.

JUNIOR SCIENTIFIC OFFICER (male or female, with an honours degree in science, pharmacy or biology), for duties consisting of technical work in the Blood Transfusion Service Laboratories—The Director, Blood Transfusion Service, Roby Street, Manchester 1.

LABORATORY TECHNOLOGIST (male or female, A.I M.L.T., and preferably experience in serological techniques and tissue culture connected with virology) with the West African Council for Medical Research (Virus Research Unit, Yaba, Nigeria)—The Crown Agents, 4 Millbank, London, S.W.1, quoting Ref. M.3C/52407/NF.

PLANT PHYSIOLOGISTS (2) (with a good honours degree in botany or natural science with two years suitable postgraduate training or experience) at the West African Institute for Oil Palm Research, Nigeria; one to review present methods of production and initiate ways of increasing the supply of palm oil, and the other to carry out leaf analysis and other investigations into the nutrition of the oil palm—The Director of Recruitment, Colonial Office, London, S.W.1, quoting BCD.197/199/013.

SENIOR LECTURER (preferably with a higher degree in chemical engineering and several years teaching experience at university or technical college level) IN CHEMICAL ENGINEERING at the University of Mandalay, Burma—The Ministry of Labour and National Service (E.9), 26–28 King Street, London, S.W.1, quoting A.12/BUR/TCS/217.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement)

Great Britain and Ireland

Southern Regional Council for Further Education. Eleventh Annual Report, October 1958. Pp. 36. (Reading: Southern Regional Council for Further Education, 1958.) [2611

Year Book of the Physical Society, 1958. Pp. v+106. (London: Physical Society, 1958.) 12*s.* 6*d.* [2611

Royal Institute of Chemistry. Lectures, Monographs and Reports, 1958. No. 3: Modern Aspects of Thermochemistry. By Dr. H. A. Skinner. Pp. ii+52. (London: Royal Institute of Chemistry, 1958.) 6*s.* net. [2611

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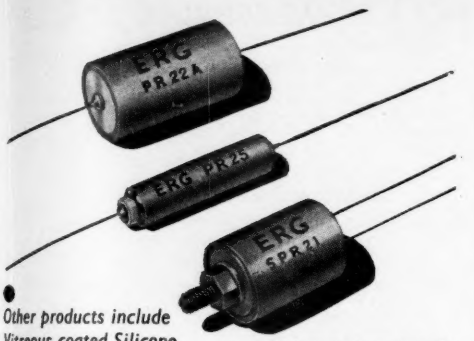

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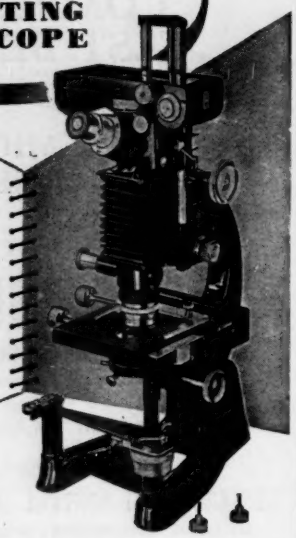

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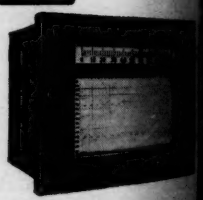

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